Iron and Steel Engineer

Established 1907 as Proceedings of A. I. & S. E. E.

J. F. KELLY, Editor

CONTENTS

Volume VI. SEPTEMBER, 1929 Number IX.

Honorary Members, Board of Directors and National Committees of the A. I. & S. E. E., for the year 1929-1930 III

Short-Circuit Study Applied to a Steel Plant Power Transmission System—By R. M. Hussey 497

Discussion—
Presented by L. A. Terven, A. C. Cummins, A. G. Darling, G. P. Wilson, B. M. Jones and J. S. Murray 512

Cleaning Air by the Adhesive Impingement Method—
By J. H. Milliken 521

Spring End Trucks for Cranes—
By John Muntz 525

Discussion—Surveys of Lighting and Voltage in the Steel Industry—
Presented by A. J. Standing, H. L. Johnson, A. J. Thompson, George W. Pieffer and S. G. Hibben 526

Items of Interest 531

List of Advertisers VI

Published Monthly by

Association of Iron and Steel Electrical Engineers

BOARD OF DIRECTORS—1929-1930

PRESIDENT, F. W. CRAMER, Republic Iron and Steel Co., Youngstown, Ohio

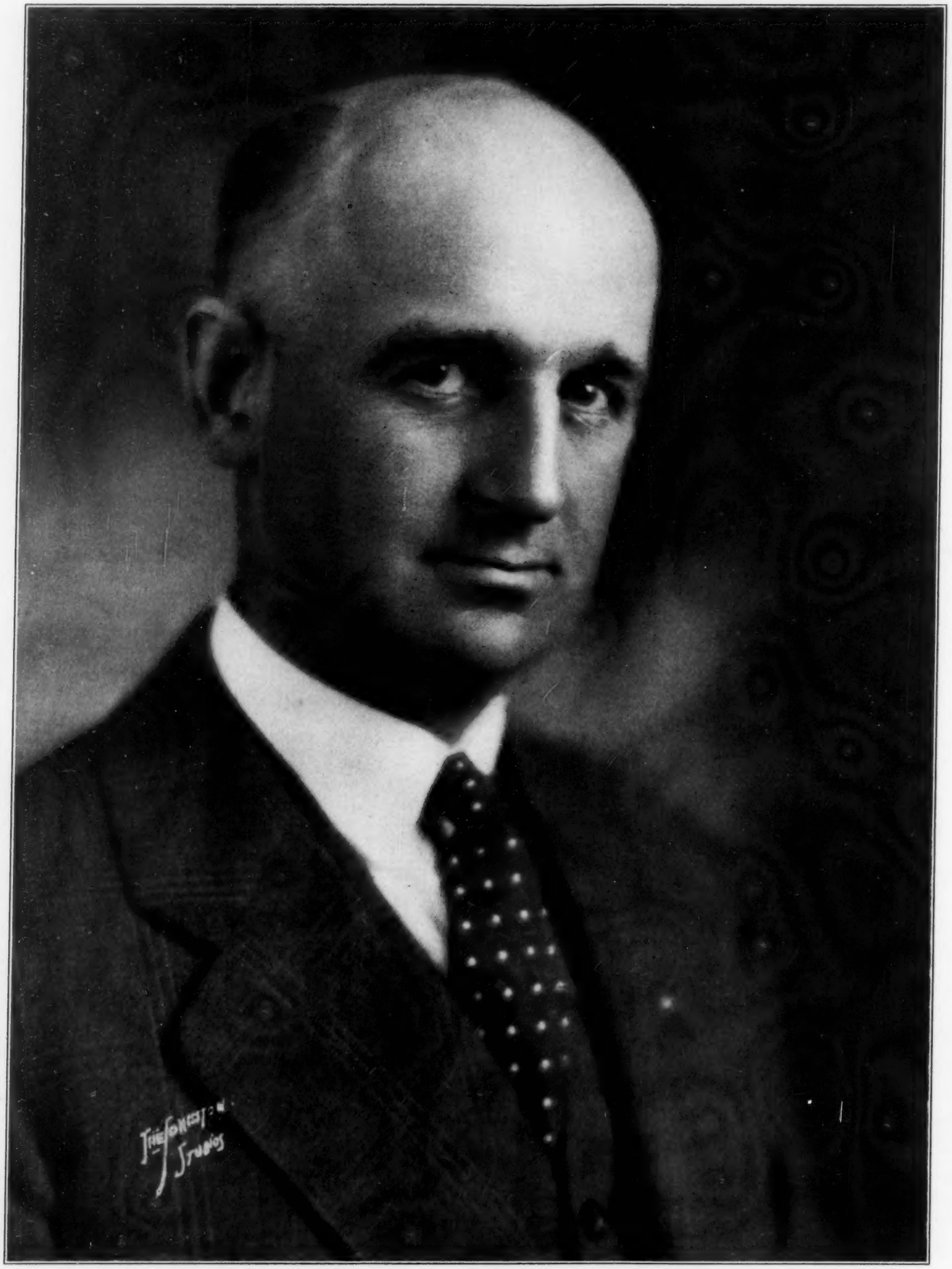
FIRST VICE PRESIDENT, R. M. HUSSEY—Jones & Laughlin Steel Corp., Aliquippa, Pa.
SECOND VICE PRESIDENT, F. O. SCHNURE—Bethlehem Steel Co., Sparrows Point, Md.
TREASURER, JAMES FARRINGTON—Wheeling Steel Corp., Steubenville, Ohio.
SECRETARY, W. E. MILLER—Bethlehem Steel Company, Johnstown, Pa.
PAST PRESIDENT, C. S. PROUDFOOT—Vanadium Corp. of America, Niagara Falls, N. Y.
PAST PRESIDENT, A. J. STANDING—Bethlehem Steel Company, Bethlehem, Pa.
DIRECTOR AT LARGE, S. S. WALES—Carnegie Steel Company, Pittsburgh, Pa.

DIRECTOR, F. E. LEAHY—Youngstown Sheet & Tube Company, Youngstown, Ohio.
DIRECTOR, WALTER GREENWOOD—Youngstown, Ohio.
DIRECTOR, G. A. LAMBERTON—National Tube Company, Lorain, O.
DIRECTOR, L. C. EDGAR—Carnegie Steel Company, Braddock, Pa.
DIRECTOR, J. J. BOOTH—National Tube Company, Gary, Indiana.
DIRECTOR, GEO. PFEFFER—Florence Pipe Foundry & Machine Co., Florence, N. J.
DIRECTOR, E. P. WINTERS—Sloss Sheffield Iron & Steel Co., Birmingham, Ala.

HONORARY DIRECTOR, E. FRIEDLAENDER—Pittsburgh, Pa.

JOHN F. KELLY, Managing Director—Empire Building, Pittsburgh, Pa.

Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879.
Subscription Price $5.00 per Year. Single Copy 50c



Mr. R. M. Hussey, Electrical Superintendent of Jones & Laughlin Steel Corporation, Aliquippa, Pa., also first Vice President Association of Iron & Steel Electrical Engineers. Mr. Hussey is an active member of the Association, takes a keen interest in all of its activities, and is offering on page 497 an engineering contribution in the form of a paper entitled, "A Study of Short Circuit Problems as Applied to a Steel Plant Power Transmission System." The study covers a period beginning with the year 1916 until 1929. The paper also describes how many of the short circuit problems were eliminated. The Association of Iron and Steel Electrical Engineers is fortunate in having Mr. Hussey's experiences in their transactions for future references in cases of trouble in other plants.

Association of Iron and Steel Electrical Engineers

Board of Directors, Honorary Members and National Committees of the Association of Iron and Steel Electrical Engineers.

HONORARY MEMBERS

R. H. McMASTER, President, Steel Co. of Canada, Ltd., Hamilton, Ontario, Canada.
A. C. PINKEY, President, Midvale Steel Co., Philadelphia, Pa.
E. G. GRACE, President, Bethlehem Steel Corp., S. Bethlehem, Pa.
W. C. CLYDE, President, Carnegie Steel Co., Pittsburgh, Pa.
W. H. DONNER, President, Donner Steel Co., Buffalo, N. Y.
GANO DUNN, President, J. G. White Engr. Co., New York, N. Y.
TAYLOR ALLDERDICE, Pittsburgh, Pa.
E. J. BUFFINGTON, President, Illinois Steel Co., Chicago, Ill.

BOARD OF DIRECTORS—1929-1930

PRESIDENT, F. W. CRAMER—Chief Elec. Engr., Republic Iron & Steel Company, Youngstown, Ohio

FIRST VICE PRESIDENT, R. M. HUSSEY—Electrical Supt., Jones & Laughlin Steel Corp., Aliquippa, Pa.
SECOND VICE PRESIDENT, F. O. SCHNURE—Electrical Supt., Bethlehem Steel Company, Sparrows Point, Md.
TREASURER, JAMES FARRINGTON—Electrical Supt., Wheeling Steel Corp., Steubenville, Ohio.
SECRETARY, W. E. MILLER—Electrical Supt., Bethlehem Steel Company, Johnstown, Pa.
PAST PRESIDENT, C. S. PROUDFOOT—General Mgr., Vanadium Corp, of America, Niagara Falls, N. Y.
PAST PRESIDENT, A. J. STANDING—Electrical Supt., Bethlehem Steel Company, Bethlehem, Pa.
DIRECTOR AT LARGE, S. S. WALES—Chief Electrical Engr., Carnegie Steel Co., Pittsburgh, Pa.
DIRECTOR, F. E. LEAHY—Combustion Engineer, Youngstown Sheet & Tube Co., Youngstown, Ohio.
DIRECTOR, WALTER GREENWOOD—Youngstown, Ohio.
DIRECTOR, J. J. BOOTH—Asst. Electrical Supt., National Tube Co., Gary, Ind.
DIRECTOR, E. P. WINTERS—Power Engr., Sloss, Sheffield Steel & Iron Co., Birmingham, Ala.
DIRECTOR, G. A. LAMBERTON—Electrical Dept., National Tube Co., Lorain, Ohio.
DIRECTOR, L. C. EDGAR—Chief Engr., Carnegie Steel Co., Braddock, Pa.
DIRECTOR, GEO. W. PFEFFER—Electrical Supt., Florence Pipe Foundry & Machine Co., Florence, N. J.
HONORARY DIRECTOR, E. FRIEDLAENDER—Pittsburgh, Pa.

JOHN F. KELLY, Managing Director—Empire Building, Pittsburgh, Pa.

NATIONAL COMMITTEES FOR 1929-1930

STANDARDIZATION COMMITTEE

Chairman, F. D. Egan, Elec. Supt., Bethlehem Steel Co., Lackawanna, N. Y.
W. S. Hall, Elec. Supt., Illinois Steel Co., S. Chicago, Ill.
A. W. Steed, Supt. Maint., American Rolling Mills Co., Middletown, Ohio.
E. S. Jefferies, Elec. Engr., Steel Co. of Canada, Ltd., Hamilton, Canada.
W. T. Snyder, Supt. Power & Con., National Tube Co., McKeesport, Pa.
J. E. Fries, Chief Engr., Tenn. Coal Iron & R. R. Co., Birmingham, Ala.
James Farrington, Elec. Supt., Wheeling Steel Corp., Steubenville, Ohio.
R. M. Hussey, Elec. Supt., Jones & Laughlin Steel Corp., Aliquippa, Pa.
A. J. Standing, Elec. Supt., Bethlehem Steel Co., Bethlehem, Pa.

PAPERS COMMITTEE

Chairman, A. C. Cummins, Elec. Supt., Carnegie Steel Co., Duquesne, Pa.
W. N. Flanagan, Special Engr., Carnegie Steel Co., Pittsburgh, Pa.
J. C. Reed, Elec. Supt., Bethlehem Steel Co., Steelton, Pa.
F. L. Foss, Asst. to Pres., Wheeling Steel Corp., Wheeling, W. Va.
E. S. Jefferies, Elec. Engr., Steel Company of Canada Hamilton, Ont., Canada.
J. J. Booth, Asst. Elec. Supt., National Tube Co., Gary, Ind.
K. A. Simon, Research Physicist, Tenn. Coal, Iron & R. R. Co., Ensley, Ala.
A. L. Foell, Chief Engr, Donner Steel Co., Buffalo, N. Y.
C. A. Menk, Elec. Supt., Carnegie Steel Co., Homestead, Pa.
S. S. Wales, Chief Elec. Engr., Carnegie Steel Co., Pittsburgh, Pa.
W. B. Shirk, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
J. D. Wright, Engineer, General Electric Co., Schenectady, N. Y.
A. M. McCutcheon, Vice Pres., Reliance Elec. & Engr. Co., Cleveland, Ohio.
R. W. Davis, Engineer, Allis Chalmers Mfg. Co., Milwaukee, Wisc.

EDITING COMMITTEE

Chairman, F. O. Schnure, Elec. Supt., Bethlehem Steel Co., Sparrows Point, Md.
R. S. Shoemaker, Supt. Rolling Mills, American Rolling Mill Co., Middletown, Ohio.
C. L. Baker, Management's Repr., Bethlehem Steel Co., Buffalo, N. Y.
L. C. Edgar, Chief Engr., Edgar Thomson Works, Carnegie Steel Co., Braddock, Pa.
Wray Dudley, Elec. Engr., National Tube Co., Pittsburgh, Pa.
F. A. Wiley, Elec. Supt., Wisconsin Steel Co., Chicago, Ill.
F. E. Leahy, Fuel Engr., Youngstown Sheet & Tube Co., Youngstown, O.

DEVELOPMENTS IN ROLLING MILL PRACTICES COMMITTEE

Chairman, R. S. Shoemaker, Supt. Rolling Mills, American Rolling Mill Co., Middletown, O.
J. H. Van Campen, Ch. Engr., Trumbull Plant, Republic Iron & Steel Co., Warren, O.
W. H. Ramage, Pres., Valley Mould & Iron Co., Hubbard, O.
Louis C. Edgar, Chief Engr., Edgar Thomson Works, Carnegie Steel Co., Braddock, Pa.
C. H. Hunt, Chief Engr., Weirton Steel Co., Weirton, W. Va.
G. L. Warren, Chief Engr., Sharon Steel Hoop Co., Sharon, Pa.

MEMBERSHIP COMMITTEE

Chairman, H. E. Davis, Elec. Supt., Interstate Iron & Steel Co., S. Chicago, Ill.
E. H. Wentz, Elec. Supt., National Tube Co., Lorain, Ohio.
M. E. McGrail, M. M., Great Lakes Steel Co., Ecourse, Mich.
R. L. McIntosh, Elec. Supt., Inland Steel Co., Indiana Harbor, Ind.
E. C. Marshall, Elec. Supt., Youngstown Sheet & Tube Co., Indiana Harbor, Ind.
H. B. Conover, M. M., Carnegie Steel Co., Mingo Junction, Ohio.
A. J. Whitcomb, Elec. Engr., Freyn Engineering Co., Chicago, Ill.
N. Farrar, Dist. Mgr., Harnischfeger Corp., Milwaukee, Wisc.
Kenneth Raynor, Asst. Elec. Supt., Bethlehem Steel Co., Bethlehem, Pa.
Linn O. Morrow, Elec. Engr., Schaff Bldg., Philadelphia, Penna.
W. W. Garrett, Elec. Engr., Tenn. Coal Iron & R. R. Co., Ensley, Ala.
J. E. Wood, Sales Engr., Monitor Controller Co., 1940 East 6th St., Cleveland, Ohio.
E. A. Hurme, Engr., Clark Controller Co., Empire Blgd., Pittsburgh, Pa.
M. J. Conway, Comb. Engr., Lukens Steel Co., Coatesville, Pa.
R. R. Shepherd, Elec. & Mech. Engr., A. M. Byers Co., Ambridge, Pa.
A. R. Lintern, Secretary, Nichols Lintern Co., Cleveland, Ohio.
L. Ellman, Vice Pres., M. H. Detrick Co., Empire Bldg., Pittsburgh, Pa.
J. F. Spellacy, Gen. Supt., Wheeling Steel Corp., Steubenville, Ohio.
J. Leo Scanlon, Sales Engr., Ellicott Square Bldg., Buffalo, N. Y.
G. R. Thatcher, Elec. Engr., Midland Coke & Iron Corp., St. Louis, Mo.

SPECIAL COMMITTEE ON BEARINGS

Chairman, F. D. Egan, Elec. Supt., Bethlehem Steel Co., Lackawanna, N. Y.
D. M. Petty, Elec. Supt., Bethlehem Steel Co., Bethlehem, Pa.
E. Lewis, Elec. Supt., Youngstown Sheet & Tube Co., Youngstown, O.
J. H. Van Campen, Ch. Engr., Republic Iron & Steel Co., Warren, O.
R. H. DeMott, SKF Industries, Inc., New York, N. Y.
J. M. Kelly, Hyatt Roller Bearing Co., Pittsburgh, Pa.
Fred Waldorf, Timken Roller Bearing Co., Pittsburgh, Pa.
D. E. Batesole, Norma Hoffman Bearing Corp., Stamford, Conn.
H. R. Reynolds, Fafnir Bearing Co., New Britain, Conn.
Samuel Farrell, Rollway Bearing Co., Syracuse, N. Y.
L. A. Cummings, Ch. Engr., Marlin Rockwell Corp., Jamestown, N. Y.
R. J. Harry, E.E., Carnegie Steel Co., Homestead, Pa.
J. D. Scully, Elec. Supt., National Tube Co., McKeesport, Pa.
H. C. Mosley, Elec. Supt., Wheeling Steel Corp., Portsmouth, Ohio.
R. L. Brown, New Departure Mfg. Co., Bristol, Conn.
C. J. Swan, Orange Roller Bearing Co., Orange, N. J.
W. C. Suppler, Elec. Supt., Tenn. Coal Iron & R. R. Co., Ensley, Ala.
C. J. Smith, Asst. E. E., Illinois Steel Co., So. Chicago, Ill.
E. C. Marshall, E. E., Youngstown Sheet & Tube Co., Indiana Harbor, Ind.
R. F. Chaffin, Supt. Power, Pittsburgh Crucible Steel Co., Midland, Pa.

ILLUMINATION COMMITTEE

Chairman, G. J. Walz, Asst. Elect. Supt., Bethlehem Steel Co., Steelton, Pa.
P. C. Keller, Ivanhoe Div. of the Miller Co., Cleveland, O.
S. G. Hibben, Com. Mgr., Westinghouse Lamp Co., Bloomfield, N. J.
A. C. Cummins, Elec. Supt., Carnegie Steel Co., Duquesne, Pa.
H. J. Walter, Asst. Elec. Supt., Jones & Laughlin Steel Corp., Pittsburgh, Pa.
A. R. Lintern, Sec., Nichols Lintern Co., Cleveland, O.
C. W. Roy, Sales Engr., Wheeler Reflector Co., Pittsburgh, Pa.
A. J. Thompson, Pres., Thompson Electric Co., Cleve-
J. C. Ritchey, Elec. Engr., Pressed Steel Car Co., McKees Rocks, Pa.
D. W. Blakeslee, Illum. Engr., Pittsburgh, Pa.
D. H. Tuck, Engr., Holophone Co., New York, N. Y.
B. G. Kodjbanoff, Mgr., Benjamin Elec. Mfg. Co., New York, N. Y.
Ward Harrison, Dir. of Illumination, National Lamp Works, Cleveland, O.
F. A. Tremellen, Gen. Foreman, Bethlehem Steel Co., Johnstown, Pa.

WELDING COMMITTEE

Chairman, S. S. Wales, Chief Elec. Engr., Carnegie Steel Co., Pittsburgh, Pa.
A. W. Steed, Supt. of Maint., American Rolling Mill Company, Middletown, Ohio.
R. M. Hussey, Elec. Supt., Jones & Laughlin Steel Corp., Aliquippa, Pa.
A. J. Standing, Elec. Supt., Saucon Plant, Bethlehem Steel Co., Bethlehem, Pa.
J. H. McElhinney, Gen. Supt., Lukens Steel Co., Coatesville, Pa.
Elbert Lewis, Asst. Elec. Supt., Illinois Steel Co., South Chicago, Ill.
J. C. Reed, Elec. Supt., Bethlehem Steel Co., Steelton, Pa.
A. B. Churchill, Elec. Supt., American Bridge Co., Ambridge, Pa.
W. W. Garrett, Elec. Engr., Tenn. Coal Iron & R. R. Co., Ensley, Ala.
Grover Hughes, Elec. Engr., Truscon Steel Co., Youngstown, O.
E. L. Upp, Elec. Supt., National Tube Co., Gary, Ind.
E. Tyler Davis, V. P. Tyler Tube & Pipe Co., Washington, Pa.
J. S. O'Donovan, Elec. Supt., Spang Chalfant Co., Etna, Pa.

ELECTRIC HEAT COMMITTEE

Chairman, C. S. Proudfoot, Genl. Mgr., Vanadium Corp. of America, Niagara Falls, N. Y.
Wirt Scott, Westinghouse Elec. & Mfg. Co., Mansfield, Ohio.
R. W. Heller, Power Engr., Duquesne Light Co., Pittsburgh, Pa.
R. M. Cherry, Engr., General Electric Co., Schenectady, N. Y.
W. W. Wallis, President, Pittsburgh Electric Furnace Co., Pittsburgh, Pa.
R. J. Hartley, Engr., Simmons Saw & Steel Co., Lockport, N. Y.
E. N. Calhoun, Sales Mgr., Edwin L. Wiegand Co., Pittsburgh, Pa.
C. F. Cone, Engr., Geo. J. Hagan Co., Pittsburgh, Pa.
F. C. Watson, Elec Engr., International Nickel Co., Huntington, W. Va.
J. D. Donovan, Elec. & Mech. Supt., Central Alloy Steel Company, Massillon, Ohio.
R. F. Benzinger, Vice Pres., Electric Furnace Co., Salem, O.
E. F. Northrup, Vice Pres., Ajax Electro Thermic Corp., Philadelphia, Pa.
S. Arnold, Heroult Electric Furnaces, Pittsburgh, Pa.

ELECTRICAL DEVELOPMENTS COMMITTEE

Chairman, W. H. Burr, Elec. Supt., Lukens Steel Co., Coatesville, Pa.

Main Roll Division

W. B. Shirk, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
J. D. Wright, General Electric Co., Schenectady, N. Y.
R. W. Davis, Allis Chalmers Mfg. Co., Milwaukee, Wisc.
W. H. Feldman, Electric Machinery Mfg. Co., Minneapolis, Minn.
A. C. Bunker, Crocker Wheeler Elec. Mfg. Co., Ampere, N. J.

Auxiliary Drives and General Purpose Motors Division

A. M. McCutcheon, Reliance Elec. & Engr. Co., Cleveland, O.
J. R. Lewis, Crocker Wheeler Elec. Mfg. Co., Pittsburgh, Pa.
J. C. Barry, General Electric Co., Erie, Pa.
D. W. Deans, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
W. H. Powell, Allis Chalmers Mfg. Co., Milwaukee, Wisc.
J. S. Lincoln, Lincoln Electric Co., Cleveland, O.
H. S. Stockdale, Electro Dynamo Co., Pittsburgh, Pa.
L. H. Tippins, U. S. Electrical Mfg. Co., Pittsburgh, Pa.

Control Division

N. L. Mortensen, Cutler Hammer Mfg. Co., Milwaukee, Wisc.
W. H. Williams, Clark Controller Co., Cleveland, Ohio.
R. G. Widdows, Electric Con. & Mfg. Co., Cleveland, O.
L. A. Umansky, General Electric Co., Schenectady, N. Y.
E. B. Newell, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Jos. F. Frese, Monitor Controller Co., Baltimore, Md.
J. S. Rowan, Rowan Controller Co., Baltimore, Md.

Crane Division

G. W. Yanney, Alliance Machine Co., Alliance, O.
F. H. Barnard, Morgan Engineering Co., Alliance, O.
F. J. Brittingham, Cleveland Crane & Engr. Co., Pittsburgh, Pa.
Eric Zachau, Manning Maxwell & Moore, Muskegon, Mich.
Sidney Buckley, Niles Bement Pond Co., Philadelphia, Pa.
Norman Farrar, Harnischfeger Corp., Milwaukee, Wisc.
H. A. Baugh, Shepard Elec. Crane & Hoist Co., Chicago, Ill.
H. P. O'Neil, Milwaukee Elec. Crane & Hoist Co., Milwaukee, Wisc.

Transmission Equipment Division

F. E. Fairman, General Electric Co., Schenectady, N. Y.
G. P. Wilson, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Samuel Horelick, Pennsylvania Transformer Co., Pittsburgh, Pa.
G. L. Crosby, Roller Smith Co., New York, N. Y.
P. C. Gunion, ITE Circuit Breaker Co., Philadelphia, Pa.
R. F. Gooding, Condit Elec. Mfg. Corp., Pittsburgh, Pa.
A. F. Alsaker, Delta Star Electric Co., Chicago, Ill.
R. E. Zimmerman, Railway & Ind. Engr. Co., Greensburg, Pa.
L. R. Lewis, Electric Power Equipment Corp., Philadelphia, Pa.
J. J. Mullen, Moloney Electric Co., St. Louis, Mo.
J. S. Livingston, Schweitzer & Conrad, Chicago, Ill.
L. B. Gawthrop, Electric Service Supplies Co., Philadelphia, Pa.
Grover W. Lapp, Lapp Insulator Co., LeRoy, N. Y.
W. W. Lewis, General Electric Co., Schenectady, N. Y.
K. A. Hawley, Locke Insulator Co., Baltimore, Md.
H. B. Vincent, R. Thomas & Sons, East Liverpool, O.
D. C. Hopper, Duquesne Light Co., Pittsburgh, Pa.
R. L. Baker, Metropolitan Edison Co., Reading, Pa.
M. E. Noyes, Aluminum Co. of America, Pittsburgh, Pa.
H. E. Ransford, G. & W. Electric Specialties Co., Pittsburgh, Pa.
A. F. Hovey, Standard Underground Cable Co., Pittsburgh, Pa.
J. J. O'Brien, Okonite Co., Chicago, Ill.
J. S. Rashba, Rockbestos Products Corp., Pittsburgh, Pa.
A. N. Cartwright, West Penn Power Co., Pittsburgh, Pa.
R. F. Mason, International Nickel Corp., New York, N. Y.

Generating Equipment Division

R. H. Wright, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Saul Lavine, General Electric Co., Pittsburgh, Pa.
W. H. Powell, Allis Chalmers Mfg. Co., Milwaukee, Wisc.

Miscellaneous Division

C. L. Snyder, Appleon Electric Co., Pittsburgh, Pa.
J. J. Bangert, Grouse Hinds Co., Pittsburgh, Pa.
M. S. Robinson, Erie Malleable Iron Co., Pittsburgh, Pa.
A. E. Tregenza, Jefferson Electric Co., Chicago, Ill.
E. P. Burns, V. V. Fittings Co., Philadelphia, Pa.
T. P. McGinnis, Pyle National Co., Pittsburgh, Pa.
C. C. Lafferty, National Electric Products Co., Chicago, Ill.
W. D. Hodson, Hodson Corporation, Chicago, Ill.
C. O. Norstrum, Keystone Lubricating Co., Philadelphia, Pa.
Geo. P. Dempler, Geo. P. Dempler Co., Pittsburgh, Pa.

Instruments

R. M. Walker, Bristol Co., Pittsburgh, Pa.
A. R. Richardson, General Electric Co., Philadelphia, Pa.
G. L. Crosby, Roller Smith Co., New York, N. Y.
W. B. Shirk, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
L. D. Joralemon, Weston Electrical Instrument Co., Philadelphia, Pa.
H. F. Darby, Jr., Jewell Electrical Instrument Co., Philadelphia, Pa.

PORTABLE ELECTRICAL TOOL COMMITTEE

Chairman, A. L. Reichert, Elec. Supt., Bourne Fuller Co., Cleveland, O.
W. C. Buske, Master Mech., McConway & Torley Co., Pittsburgh, Pa.
A. F. Jones, Chief Elec., Champion Machine & Forging Co., Cleveland, O.
F. M. Sturgess, Chief Elect., American Steel & Wire Co., Fairfield, Ala.
W. C. McClelland, Elec. Supt., Standard Tin Plate Co., Canonsburg, Pa.
George H. McFeaters, Elec. Engr., Lorain Steel Co., Johnstown, Pa.
S. E. McQuigg, Chief Elect., Allegheny Steel Co., Brackenridge, Pa.
P. J. McGrane, Chief Elec., Railway Steel Spring Co., Chicago Heights, Ill.
James Maloney, Chief Elect., Superior Steel Co., Carnegie, Pa.
Henry Molz, Chief Elec., Allegheny River Mining Co., Kittanning, Pa.
J. R. Penman, Elec. Supt., Reading Iron Co., Reading, Pa.
C. J. Garrigan, Elec. Engr., Pittsburgh Rolls Corp., Pittsburgh, Pa.
J. S. O'Donovan, Elec. Supt., Spang Chalfant Co., Etna, Pa.

(Continued on Page 528)

INDEX TO ADVERTISERS

A

Alliance Machine Company 579
Allis Chalmers Mfg. Company 598
Aluminum Company of America 536
American Gas Association 544
Appleton Electric Company 605

B

Bartlett Hayward Company 607
Baker Raulang Company 559
Blaw Knox Company 546
E. W. Bliss Company 565
Benjamin Electric Mfg. Co. 600
Bull Dog Electric Products Co. 610

C

Chapman Stein Company 554
Clark Controller Company 551
Cleveland Crane & Engineering Co. 582
Combustion Engineering Corp. 532–564
Colts Patent Fire Arms Mfg. Co. 592
Crocker Wheeler Elec. Mfg. Co. 558
Crouse Hinds Company 537
Cutler Hammer, Inc. 543–555–599

D

De Laval Steam Turbine Company 575–577
Delta Star Electric Company 578
M. H. Detrick Company 612
Doubleday Hill Electric Co. 575
Duquesne Light Company 581

E

Economy Fuse & Mfg. Co. 586
Electric Controller & Mfg. Co. 563–587
Electric Machinery Mfg. Co. 566
Electric Power Equipment Corp. 601
Electrical Engineers Equipment Co. 574
Electro Dynamic Company 604
Erie Malleable Iron Co. 585

F

Farrel Birmingham Company, Inc. 540
Franklin Electric & Cons. Co. 576
Freyn Engineering Company 595–596

G

General Electric Company Cover-4-538-539
Graybar Electric Company 571

H

Harnischfeger Corp. 606
Holophane Company, Inc. 611
Hyatt Roller Bearing Company 583

I

Ideal Commutator Dresser Company 577
International Nickel Company, Inc. 584
Iron City Electric Company 578
ITE Circuit Breaker Company Cover 3
Ivanhoe Division of the Miller Co. 568

J

Jefferson Electric Company 590

K

Keystone Lubricating Company 553

L

Lapp Insulator Company 552

M

Martindale Electric Company 567
Moloney Electric Company 574
Morgan Construction Company 545
Morgan Engineering Company 557
Morganite Brush Company 571

N

National Air Filter Company 589
National Carbon Company 541
New Departure Mfg. Company 603
Nichols Lintern Company 547
Norma Hoffmann Bearings Corp. 593

O

Ohio Electric & Controller Company 560
Okonite Company 549

P

B. F. Perkins & Son, Inc. 570

R

Railway & Industrial Engineering Co. 594
Reed Air Filter Company 609
Reliance Electric & Engineering Co. 535
Rockbestos Products Corp. 602
Roller Smith Company 576
Rowan Controller Company 570
Rumsey Electric Company 580

S

Selden Company 556
Shepard Niles Crane & Hoist Corp. 562
SKF Industries, Inc. 561
Stackpole Carbon Company Cover 1
Standard Underground Cable Company 542

T

Thompson Electric Company 573
Timken Roller Bearing Company 550
Trico Fuse Mfg. Co. 569

U

U. S. Electrical Mfg. Co. 608
Union Electric Mfg. Co. 572
R. E. Uptegraff Mfg. Co. 580

V

V. V. Fittings Company 588

W

Weston Electrical Instrument Corp. 573
Westinghouse Electric & Mfg. Co. Cover 2-548-572-591
Geo. D. Whitcomb Co. 534
Edwin L. Wiegand Company 597

"Short Circuit Study Applied to a Steel Plant Power Transmission System"*

By R. M. HUSSEY

It is not intended that this paper shall be a highly technical treatise but rather a comprehensive description of an existing steel plant power system and the practical application of a short-circuit study and the use made of knowledge obtained from such a study. It is the description of a power system which for some few years was served by a comparatively small amount of power generating capacity and was equipped originally with switch gear based on currents which utilization equipment would use rather than on those currents which even the small generators might produce in times of trouble.

The description begins with a period just prior to that time when a large generator was installed, when more circuits were installed and paralleled in order to transmit more power, and leads through some troubles that began to appear or were made worse by reason of more power on the system, to the time when more large generator installations were made and troubles became more frequent and severe, on through the inception of a short circuit study, the actual study, and finally to the program for revamping the entire system in accordance with what was learned in the short-circuit study.

The revamping and new construction work which has since been done is described very carefully.

There is no doubt as to improved operations obtaining as the result of such work but, as a number of different things were done, it is difficult, in many cases, to say just what part of the work has done the most good. It would be a matter of personal opinion in some cases as to just what benefits have been derived from certain pieces of work. In general, however, we have held to facts and figures as much as possible with the idea in mind of making this a useful contribution to the Association's proceedings.

The author of this paper will not try to describe the system as it existed prior to the time he first became connected with this particular steel plant. There does not seem to be sufficient data at hand to assure a good description prior to 1915.

(1) Description of System As It Was Prior to 1923

In the early part of 1916 the 6600-volt power generation and transmission system comprised two (2) 4620-KVA turbo-generators, two (2) 1000-KVA reciprocating engine generator sets, one (1) 750-KVA turbo-generator, two (2) 4/0 bare circuits each about 9000 feet long, two (2) 2/0 bare circuits each about 3000 feet long, and two (2) branch circuits each about 2000 feet long. The combined generator capacity amounted to 11,990 KVA, but never was there more than 9,240 KVA on the line at any time.

The 6600-volt power used at that time was either converted through one (1) 1000-KW M-G set, one (1) 300-KW rotary converter, three (3) 500-KW rotary converters and one (1) 500-KW M-G set, or transformed through one (1) 1350-KVA, one (1) 3000-KVA, one (1) 1500-KVA, and one (1) 450-KVA transformer bank, or used in four (4) 650-HP, 6600-volt pump motors.

The switching equipment, exclusive of that connected to the five (5) 6600-volt generators, was on the order of 300-ampere capacity, some of single tank design, some of three (3) tank design, some with heavy wooden fillers in the tanks that permitted an oil capacity per single tank of no more than three (3) or four (4) quarts; all of it manually operated. The switching equipment was figured for the utilization equipment rating with some excess rating for overloads, but not for any thermal capacity or rupturing capacity consistent with generator capacity ordinarily connected to the system. A typical oil switch installation on utilization equipment application was a 300-ampere, single tank, oil switch with a rupturing capacity of less than 1500 amperes on 7500 volts, connected to a 120-ampere, 6600-volt load, in the power house almost directly off the 6600-volt bus.

Very little information is at hand as to transmission line characteristics. Pin-type insulators rated at 7500-volts were used on 24" centers, in the shape of an equilateral triangle; spans were about 125 feet long; and the few outdoor cable terminals in use were of the 7500-volt class.

Information on circuit troubles, switch failures or generator troubles is also very meagre; the author does not recall any serious troubles of any kind.

In the summer of 1916 plant extensions were underway. The initial installation of a Welded Tube Department was made. It involved a 10" Skelp Mill and a motor driven 18" and 21" sheet bar and skelp mill. And so, during that year, the 6600-volt power generating capacity was increased by 20,000 KVA in a new power house, two (2) of the old transmission lines were extended to the new power house, and four (4) 4/0 bare copper circuits were installed between the two (2) power plants, all six (6) circuits being operated in parallel.

Electrical equipment installed at the Welded Tube Department included a 500-KW M-G set and a 1500-KVA transformer bank. Switches installed with this equipment were of rather low rupturing capacity, probably not greater than 1500 amperes on 7500 volts. This station was fed, however, through a lead-covered cable tapped onto one of the two (2) pump house circuits and trouble currents would not have been very great.

The 10" Skelp Mill involved 4000 HP in 6600-volt main drive motors and a small transformer bank. Here again small oil switches of 200 or 300-ampere rating for 7500-volt service, were installed under an open, bare copper bus. These switches were manually operated. This station received 6600-volt power

*Presented before Pittsburgh District Section of the A. I. & S. E. E., March 23, 1929.

over two (2) taps from two (2) of the main circuits running from one power house to the other, and it was common practice to operate with these taps paralleled at the 10″ Mill end.

The 18″ and 21″ sheet bar and skelp mill installation involved at that time, one (1) 5750-HP, 6600-volt induction motor. Two (2) 4/0 circuits fed this motor room from the North Power House. Two (2) oil switches in the motor room were used for starting the motor; one (1) a forward direction switch, the other a reverse switch. These switches were each rated 800 amperes and 15,000 volts, yet their rupturing capacity was only 2300 amperes on 7500 volts. Here again it was common practice to operate with both circuits paralleled at a bare copper bus directly over the oil switches.

The work done in 1916, therefore, more than doubled the generating capacity and produced a multiplicity of current paths, yet old switching equipment remained as it was and new switching equipment for power utilization machinery was purchased on the basis of utilization machinery ratings with practically no thought given to rupturing capacity.

During the next seven (7) years extensions were made in the Welded Tube Department and more M-G set capacity was installed there, a second 5750-HP motor was added to the Bar Mill drive on the 21″ Mill end, two (2) 5750-HP motors were installed on the Billet Mill, a second 1000-KW M-G set was installed in the North Power House, and two (2) 12,500-KVA turbo-generators were installed at the South Power House. At the end of 1923 there was 54,240 KVA in 6600-volt generator capacity on the system; 2,750 KVA in three (3) small generators in the North Power House being considered obsolete by that time. Although the generating capacity was increased by 25,000 KVA in this same period, no changes in existing switching equipment were made except at the 18″ Bar Mill.

The 21″ Bar Mill and both Billet Mill main drive installations were made late in this seven-year period, and enough information was then at hand to warrant adequate switch gear and, when the 21″ Bar Mill main drive installation was made, it carried new switching equipment for the 18″ Bar Mill end. Modern, high-rupturing capacity switches were installed in one switch room for both Bar Mill drives, and in another switch room for the Billet Mill motors.

(2) Description of Power Failures and Troubles Experienced Prior to 1923

During this same period of time troubles following the failure of some piece of electrical equipment or following some mechanical damage to outside lines became more and more severe. Tanks on the 300-ampere oil-switches at the Rod Mill Substation were damaged as frequently as trouble occurred anywhere, flash-overs on the end of the bare bus in the 10″ Skelp Mill and oil-switch damages there occurred about as frequently, in fact all those places were light, low-rated switch gear was installed, required careful examination and usually some repair work following all cases of electrical trouble on the 6600-volt system.

We have reasons for believing that a surge caused by shutting all four (4) 5750-HP motors on Billet and Bar Mills down simultaneously caused a flash-over on the end of the 10″ Skelp Mill bus that caused considerable oil switch damage.

The 7500-volt, 3-phase cable terminals or pot-heads installed out-of-doors were invariably involved in trouble; it is very likely that some caused trouble while others were damaged as a result of surges set up elsewhere. The same thing seemed to be true of some lightning arrester equipment. Bare wires in some of the longer out-of-door spans would whip together and would aggravate the troubles originating elsewhere, would burn and strand the wires so that much of it would have to be replaced and would damage many pin-type insulators as well as strain insulators at the dead ends.

Many stator windings in main drive motors were damaged and were either cut out so that operations might be resumed in the shortest possible time or in case of the worst burn-outs, replacements had to be made. The latter was particularly true in the case of 6600-volt winding failures in 1000-KW M-G sets in the North Power House. On several occasions troubles originating elsewhere on the 6600-volt system caused winding failures in the M-G set motors and damaged the 300-ampere switches connected with them.

Invariably all main drive units would kick off immediately following a case of trouble and rolling mills would be left full of steel. The whole 6600-volt net-work of main lines, tap circuits, and branch feeders were so connected and inter-connected that there was a multiplicity of paths through which current flowed into the place where some break down had occurred.

There was ever present the likelihood that operators, through carelessness or in excitement in times of trouble, would open some inter-connection by pulling open, knife-blade type of disconnecting switches. In fact this very thing occurred many times and would invariably cause more or another case of trouble and did injure some men.

All such trouble did not stop once the revamping work was started and progressed, but as we now look back we know that troubles following disturbances grew less severe, less and less work was required to restore normal operating conditions, and fewer accidents became involved.

(3) Description of Data for First Short-Circuit Study

Late in 1922 and in the early part of 1923, surveys, reports, and recommendations were made, all having to do with the adequate improvement of the 6600-volt system. As a part of this work a short-circuit study was undertaken; certain assumptions as to ultimate plant were made, physical and electrical characteristics of the system in question were recorded, reactance values of all synchronous equipment were gathered, diagrams were made, all of which, together with the other necessary information, were submitted to one of the large electrical equipment manufacturers. This manufacturer made calculations which, with all other pertinent data, were applied to the test table or calculating board at the factory. Certain spots in the 6600-volt system were selected for investigation as to short-circuit currents and current values were recorded for each of those points referred to the test table.

There is no record of just what data and information were submitted for the basis of this study of short-circuit currents. The author of this paper did not have much to do with the actual study as conducted by the electrical equipment manufacturer. It

SHORT CIRCUIT CURRENTS
DUTY ON OIL CIRCUIT BREAKERS PRESENT PLANT-EXISTING PLANT

REFERENCE DRAWING-V-774
MACHINES RUNNING 2-5500 KVA AT NORTH POWER HOUSE
1-20000 KVA AT SOUTH POWER HOUSE
1-12500 KVA AT SOUTH POWER HOUSE

TOTAL CONNECTED GENERATOR CAPACITY 43500 K.VA
SIX #0000 TIE LINES BETWEEN POWER HOUSES. REACTORS ONLY AT SOUTH POWER HOUSE

TABLE I
SHORT CIRCUIT AMPERES

LOCATION	SERVICE LINE THERMAL	SERVICE LINE RUPTURING	MOTOR OR TRANS. THERMAL
NORTH POWER HOUSE-M.G. SETS.	53500		53500
" " " FEEDERS	53500	19100	
" " " TIE LINES	41400	16400	
SOUTH POWER HOUSE-TRANS.	75500	24900	75500
" " " FEEDERS	29900	12500	29900
" " " TIE LINES			
BAR & BILLET MILLS	51500	19000	53000
SKELP MILL	43300	16700	51500
CENTRAL PUMPING STATION	28600	11400	28600
TUBE MILL	36000	14300	42000
SINTERING PLANT			39800
W&S. RY	45200	16700	45200
NAIL MILL	46700	17200	
ROD MILL	33600	13500	
COKE WORKS	21100	10050	21100

SK 3174

is reasonable to suppose that that company got all data and information they desired and that among these data and information were reactance values of all synchronous equipment, KVA ratings of all generators, number of circuits, size of cables, spacings, spans, lengths of circuits, relative locations and diagrams of connections throughout the entire system.

(4) Resume of First Short Circuit Study Report and Conclusions Drawn Therefrom

In looking over SK-3174, which shows short-circuit currents in amperes at various locations, you will note that it was the practice at that time to use 43,500 KVA in generator capacity, which was the total capacity installed, that six (6) 4/0 circuits were used as tie lines between the two power houses, that there were reactors only at South Power House where 32,500 KVA of the total generator capacity was installed, and that reference is made to Drawing V-774, which shows Present Plant-Existing System, as of that date.

In not one case shown in the tabulation on SK-3174, except South Power House feeders, did the rupturing or thermal capacities of any of the switches at locations selected for short-circuited studies equal or even approach those respective short-circuit current values which were recorded on the test table. This was characteristic of the entire 6600-volt system except at the South Power House where all switches connected directly to the bus, except the South Power House transformer switch, were of sufficient rupturing and thermal capacity. The highest short-circuit current figures shown there were on the South Power House transformer circuit, which was connected directly to the end of the 20,000-KVA machine bus through a manually operated 300-ampere oil circuit breaker. If we were to refer to the manufacturer's catalog rating we would find this switch had a rating of 300-amperes, 15,000-volts, but with a rupturing capacity of 2300 amperes on 7500 volts.

The North Power House Feeder and Tie Line breakers, which were of fairly modern design, had only about one-half sufficient rupturing and thermal capacities, while the M-G set breakers at that same station were only of 300 ampere load rating 11,000 volts but with a rupturing capacity of only 2000 Amps., yet might at some time have to stand up to a current of 53,500 amperes.

Each item on that sketch might very well be analyzed in the same way and with about the same results.

It then became only too evident that most of the switching equipment was of inadequate capacity even for the existing plant, to say nothing of any extension that would require more generator capacity.

Another tabulation is shown on SK-3175. These figures were obtained during the same test as those on SK-3174, but under slightly different conditions, as follows: The generator capacity remained the same, 43,500-KVA, but there were only four (4) 4/0 tie lines between the two power houses, reactors in all tie lines and with and without reactors in North

SHORT CIRCUIT CURRENTS

DUTY ON OIL CIRCUIT BREAKERS — PRESENT PLANT-PROPOSED SYSTEM

REFERENCE DRAWING-V-774

MACHINES RUNNING
2 - 5500 KVA AT NORTH POWER HOUSE
1 - 20000 KVA AT SOUTH POWER HOUSE
1 - 12500 KVA AT SOUTH POWER HOUSE

TOTAL CONNECTED GENERATOR CAPACITY - 43500 KVA = 3800 AMP.
4#0000 TIE LINES BETWEEN POWER HOUSES
REACTORS IN ALL TIE LINES & WITH AND WITHOUT REACTORS IN FEEDERS AT NORTH POWER HOUSE

TABLE #2

SHORT CIRCUIT AMP. — NO FEEDER REACTORS AT NORTH POWER HOUSE

LOCATION	LINE BREAKERS THERMAL	LINE BREAKERS RUPTURING	MOTOR OR TRANS. THERMAL
NORTH POWER HOUSE-TIE BR'K'RS	16400	9500	
NORTH POWER HOUSE	43200	16250	
NORTH POWER HOUSE M.G SETS			43200
SOUTH POWER HOUSE	67400	22800	
BAR & BILLET MILLS	43200	16250	43200
SKELP MILL	38400	14900	40800
CENTRAL PUMPING STATION	22500	10800	22500
TUBE MILL	21300	10000	29600
SINTERING PLANT	26200	11400	26200
W&S. RY.	20400	9750	29000
NAIL MILL	23700	10700	36000
ROD MILL	25600	11250	37700
COKE WORKS	21300	10000	21300
SOUTH POWER HOUSE TRANSF.	28700	12100	28700
WITH REACTORS IN NORTH POWER HOUSE FEEDERS			
NORTH POWER HOUSE	21300	10000	
SOUTH POWER HOUSE	29300	12100	
BAR & BILLET MILLS	21300	10000	30000
SKELP MILL	20200	9600	29700
CENTRAL PUMPING STATION	14500	7800	14500
TUBE MILL	14000	7600	21300
SINTERING PLANT	15600	8180	15600
W&S. RY.	13600	7480	20500
NAIL MILL	23700	10700	29000
ROD MILL	25600	11250	37700
COKE WORKS	21300	10000	21300
SOUTH POWER HOUSE TRANS.	28700	12100	28700
NORTH POWER HOUSE-M-G SETS			21300
NORTH POWER HOUSE TIE B'K'RS	16400	9500	

SK 3175

Power House feeder circuits, all referred to present plant but proposed system shown on V-774 as Scheme "A."

A glance at this tabulation will show some easier conditions. The South Power House transformer switch in its proposed new location would need a thermal capacity of 28,700 amperes and a rupturing capacity of 12,100 amperes compared to 75,500 and 24,900, respectively, as shown on SK-3174. The North Power House M-G set switches, without reactors in the feeder circuits, must have a thermal capacity of 43,200 amperes, compared to 53,500 amperes in the other case and with reactors in the feeder circuit at North Power House, this figure becomes 21,300 amperes; quite a reduction from 53,500 amperes to 21,300.

Many other conditions would have been similarily improved, particularly at the substations which formerly fed from usually two of the six (6) tie lines, but in the proposed Scheme "A" fed from radial type feeders, emanating from one power house or the other.

Many of these comparisons are shown on SK-5615, which has just been made for the purpose of this paper.

The differences between conditions which pro-

duced figures on SK-3174 and those on SK-3175, particularly those with reactors in North Power House, are shown quite clearly on print of V-774, Present System and Proposed System—Scheme "A". In Proposed System—Scheme "A", two (2) 4/0 circuits were combined with two others to form the equivalent of four (4) 4/0 circuits which were intended for tie lines between the two power houses and two (2) other 4/0 circuits were sectionalized by pole-top disconnecting switches to form radial type feeders from which substation taps were taken. These proposed line changes, which, by-the-way, were actually made, materially lessened the duty on many switches. It was also intended to install reactors in all feeder and tie line circuits at North Power House and to install auxiliary buses in both power houses, which would lessen switch duty still more. Many substation taps are shown arranged so that the two feeders could not be operated in parallel in the substation.

A third tabulation is shown as the result of that first short-circuit study; these figures shown on SK-3176. The conditions apply to the assumed, ultimate plant, proposed system, which was an enlargement of that shown on V-774, with a generator capacity of 95,000 KVA, six (6) 4/0 tie lines between the two power houses and reactors in all tie lines and feeders. Except for thermal capacity requirements of those switches in North and South Power Houses, the switches we have already installed would still be suitable for the ultimate. As it is not clear from any information at hand now, as to conditions determining the two high figures for North and South Power House thermal capacity, we can not state just how these two conditions could best be met.

Conclusions

It seems to the writer that the following conclusions may be drawn after careful consideration of all the foregoing matter:

That the short-circuit current figures calculated or obtained from the test table for the Present Plant —Existing System (SK-3174) revealed inadequate switch installations and a precarious operating condition. Some of our operating experiences would certainly substantiate this conclusion.

That enlargements of existing plant along same designs have created a condition that might be difficult and impractical to meet even with largest switches yet produced, and that space factor for adequate switch gear would become the determining factor in building design.

That some comparatively inexpensive line changes and rearrangement of feeder circuits and the use of reactors properly placed would materially lessen duty on oil circuit breakers, isolate line disturbances and make for continuity of operations among the various units using 6600-volt power.

That it would seem possible by practical arrangement and sectionalizing of circuits and use of reactors to keep short-circuit current values within the ratings of switches already designed and manufactured even though the assumed, ultimate plant were realized.

That there proved to be sufficient reasons for undertaking a short-circuit study.

(5) Description of Revamping Work Done in the Period 1923-1927

Before any study of short-circuit currents had been made or any final reports or recommendations

COMPARISON OF RUPTURING AND THERMAL CAPACITY REQUIREMENTS OF OIL CIRCUIT BREAKERS
REFER TO SK3174 & SK3175

LOCATION	PRESENT PLANT.					
	EXISTING SYSTEM AS OF 1923		PROPOSED SYSTEM WITH NO REACTORS AT No. POWER HOUSE		PROPOSED SYSTEM FEEDER REACTORS AT No. POWER HOUSE	
	THERMAL	RUPTURING.	THERMAL.	RUPTURING	THERMAL.	RUPTURING
NORTH POWER HOUSE TIE LINES	41400	16400	16400	9500	16400	9500
NORTH POWER HOUSE FEEDERS	53500	19100	43200	16250	21300	12100
NORTH POWER HOUSE M.G. SETS	53500		43200		21300	
SOUTH POWER HOUSE TRANSFORMERS	75500	24900	28700	12100	28700	12100
ROD MILL SUBSTATION	33600	13500	25600	11250	25600	11250
SINTER PLANT SUB STATION	39800		26200		15600	
CENTRAL PUMPING STATION	28600	11400	22500	10800	14500	7800
SKELP MILL MOTOR ROOM	43300	16700	38400	14900	20200	9600
BILLET & BAR MILL MOTOR ROOMS	51500	19000	43200	16250	21300	10000

SK 5615

had been submitted some new installations had been started right, in that modern switches of sufficient rupturing and thermal capacities were purchased with some new main drive motors, and some improvement of existing low-rupturing capacity switch conditions had been authorized. Early in 1922 a second main drive motor for the Bar Mill was purchased and with it came adequate switch gear for both the motor ordered at that time and also the one installed in 1916. This was the first installation outside the South Power House where switches of proper size were used.

New switch gear had been authorized for the Central Pumping Station and a thoroughly modern switch installation was in operation there by June, 1923. This was the first job done in the revamping program that was eventually undertaken and carried through nearly to completion at date of this paper.

The Central Pump Station is located on the river bank about 3000 feet south of the North Power House, from whence run two (2) 4/0 circuits as radial feeders to the Pumping Station. These are typical radial type feeders, one from the old bus in North Power House, and the other from a new bus in a switch tower adjacent to the North Power House, and the two feeders can not be paralleled at the Central Pumping Station end; a pump motor must be clear of one bus before it can be connected to the other bus.

The pumping station, which is of circular design in plan, was arranged for an ultimate of eight (8) 6600-volt vertical type, motor driven, centrifugal pumps. A switch house with concrete bus and switch cell work was erected on the outside of the pumping station and provisions were made for all eight (8) switches, but only six (6) switches were installed at that time. These switches are General Electric Company make, Type FH, six (6) being size 103, 500-amp, 15,000-volt, each with a rupturing capacity of 23,000 amps at 7500 volts, and a thermal capacity of 40,000 amperes for one (1) second and 25,000 amperes for five (5) seconds. One (1) switch is a 203 size, 500-amp, 7500-volt, with a rupturing capacity of 32,000 amps at 7500 volts, and a thermal capacity of 40,000 amps for one (1) second and 25,000 amps for five (5) seconds. (In further reference to rupturing and thermal capacities, let it be understood that rupturing capacity is at 7500 volts and thermal capacity for one (1) second. All these switches are described pretty much in detail in a separate tabulation and other data can be obtained from such tabulation).

By referring to short-circuit current tabulations already described for the first study, you will see that the capacities of those switches installed in the Central Pumping Station meet all conditions and seem suitable to ultimate plant requirements.

Other improvements were made at this place at the same time the new switch gear was installed; a

SHORT CIRCUIT CURRENTS
DUTY ON OIL CIRCUIT BREAKERS ULTIMATE PLANT—PROPOSED SYSTEM
REFERENCE DRAWING V-774

MACHINES RUNNING:
4-12500 KVA AT NORTH POWER HOUSE
2-12500 KVA AT SOUTH POWER HOUSE
1-20000 KVA AT SOUTH POWER HOUSE

TOTAL CONNECTED GENERATOR CAPACITY 95000 KVA.
SIX #0000 LINES BETWEEN POWER HOUSES
REACTORS IN ALL TIE LINES AND FEEDERS.
ON LINE BREAKERS DETERMINING FEATURE IS RUPTURING CAPACITY AND ON MOTOR AND TRANSFORMER BREAKERS IT IS THERMAL CAPACITY. FOR MOTOR AND TRANSFORMER BREAKERS ASSUMED TWO LINES IN PARALLEL. ON LINE BREAKERS ASSUMED ONE LINE IN USE.

TABLE NO III
SHORT CIRCUIT CURRENT IN AMPERES

LOCATION	LINE		SERVICE
	THERMAL	RUPTURING	MOTOR OR TRANS. THERMAL
NORTH POWER HOUSE	115600	41100	
SOUTH POWER HOUSE	115000	41000	
BAR MILL	31800	16550	40000
BILLET MILL	31800	16550	40600
SKELP MILL	27400	15400	44100
CENTRAL PUMPING STATION	14900	11560	14900
TUBE MILL	14000	11200	29400
SINTERING PLANT	11100	9400	11100
W. & S. Ry	27800	6000	27800
NAIL MILL	24700	14200	41000
ROD MILL	25400	14800	43100
COKE WORKS	21100	13400	21100
SOUTH POWER HOUSE - TRANSF.	29400	16200	29400
NORTH POWER HOUSE - M-G SETS.			31800

SK 3176

storage battery with automatic charging panel was installed for stand-by control power; two (2) secondary starting panels were installed and so arranged that any one of the pump motors could be started with either starter and a pushbutton, instrument and relay panel was mounted on each motor frame; all arranged in a way that made for the least amount of confusion in starting and for utmost in reliability of operations.

Operations at this station have been remarkably free of electrical troubles since such improvement work was completed.

Authorization of more high rupturing capacity switch installations was granted soon after the work was completed at the Central Pumping Station and, during the latter part of 1924, the Welded Tube Mill substation and its switch tower, the 10″ Skelp Mill motor room and the Sintering Plant substation were equipped with modern and thoroughly adequate switch gear.

The Welded Tube Mill substation at that time housed a 1000-KW M-G set and a 1500-KVA transformer bank, and was fed directly from two (2) of the ties lines through taps which terminated at a bare bus inside the station. Three hundred (300) ampere oil switches mounted exposed on pipe racks, and lightning arresters similarly installed, were all inside the station.

Fig. 1. Welded Tube Switch Station

In the revamping work, a switch house was erected near the transmission lines and two (2) line switches were installed therein because there was not enough room in the substation for all the equipment we planned to use. A concrete structure for bus and switches was erected inside the substation and both starting and running switches for two (2) 1000-KW M-G sets and for two (2) 1500-KVA transformer banks were installed therein. Since this work was started, the second M-G set and the second transformer bank have been installed.

Out-door type of lightning arresters were mounted on the roof of the switch tower and the switch tower was connected with the substation by two (2) 3-conductor lead-covered cables.

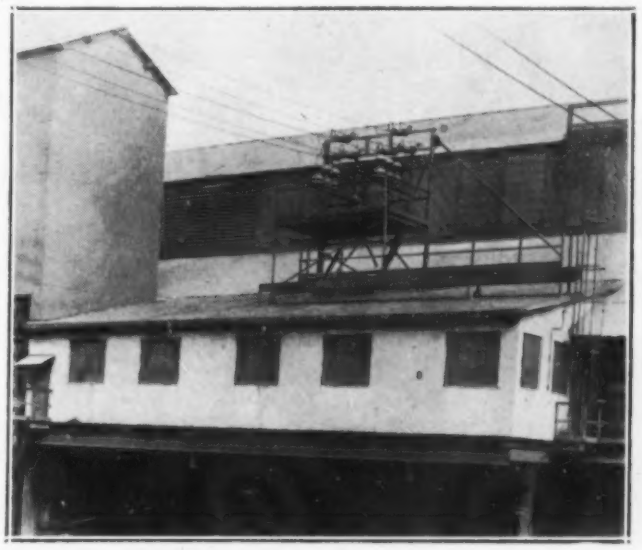


Fig. 2. Skelp Mill Switch House.

The switching equipment used on this particular job is Westinghouse make, types B-13 for feeder breakers, and OE-6 switches for the two (2) line breakers. The B-13 switches are rated 1350 amperes, 15,000 volts, and the OE-6 switches are 750 amperes, 15,000 volts.

Rupturing and thermal capacities of the B-13 switch are 5800 and 40,000 amperes, respectively; of the OE-6 switch are 32,000 and 40,000 amperes, respectively. The rupturing capacity of the B-13 switches is of course too low for short-circuit currents that might go through them, but lockout relays are provided to prevent these switches from opening under such conditions and will cause the OE-6 switches to function.

The switches used at this place seem to have capacities for meeting all conditions described in the short-circuit studies.

The 10″ Skelp Mill motor room received power in identically the same way the Welded Tube Department did and through pretty much the same kind of equipment, installed the same way. At this place a switch house was erected as a part of the revamping work, a bus and cell structure of concrete poured in place was made and line as well as motor switches were installed in the cell work. Lightning arresters were mounted on a platform on the roof.

The type of feeder circuits to this place was also changed later on, but a description of such work may be in order at this time. Instead of feeding through two (2) short taps directly from two (2) of the tie lines, two (2) radial-type feeders were strung from the North Power House. One of these two feeders now connects with the North Power

House bus and the other with the North Switch Tower bus, and are switched through two (2) line switches at the 10" Mill switch house and so arranged that the entire mill may operate from either one or the other, or both may be operated in parallel, or one line may feed one-half the mill and the other line the other half.

The switching equipment used on this job is the same as that just described for Welded Tube substation and switch house; B-13 switches for motor and transformer breakers, and OE-6 switches for the two (2) incoming lines. The same rupturing and thermal capacities given for those switches at the Tube Mill apply here.

Rupturing capacity of the line breakers is ample but the one (1) second thermal capacity may, in view of all short-circuit studies, be slightly lower than necessary, but this condition can very well be improved by installing reactors whenever needed.

The Sintering Plant substation houses a 500-KW M-G set and a 1350-KVA transformer bank. It was, and still is, fed from only one (1) 4/0 circuit about 2000 feet long, from the North Power House bus. That circuit always was of the radial feeder type and no improvements in this respect could be made. In carrying out our switching equipment improvement program at this point, a lean-to was built against the substation and a line switch, M-G set starting and running switches, transformer switch, together with necessary disconnecting switches and bus, were installed in concrete cells. The lightning arrester was mounted on a platform on the line dead-end tower.

The switches used at this point are also Westinghouse make; four (4) type B-13 breakers for M-G set and the transformer bank. No line switch is yet installed but one can be put in later, if found necessary. The thermal capacity is adequate but rupturing capacity is low; however, the rupturing capacity of the switches feeding this circuit at the North Power House is ample, and the Sintering Plant substation switches can be locked in and made in-operative under heavy, instantaneous currents.

The switching equipments for these three jobs, the Welded Tube Department substation, 10" Mill motor room, and Sintering Plant substation were purchased in one lot and the construction work was carried along on all three jobs as closely together as available forces of men would permit.

The use of equipment as described under each of the three places mentioned above, and the best layouts we were able to make at that time, have resulted in most satisfactory operations at those places; electrical troubles have been practically nil; disturbances originating in other places have not in any cases caused any troubles in these places, and in many cases have not caused interruption of power at these places.

Here were three places where switching equipment was originally of the 300-ampere rated variety and where in two places in particular and in one place almost invariably, line disturbances would cause severe electrical troubles such as flash-overs on bare bus, blow tanks off the switches, throw oil out of the tanks and in several instances 6600-volt motor windings were damaged.

In reviewing short-circuit current tabulations on SK-3174 and 3175, one will appreciate the severe duty formerly imposed on switch gear in these places.

In summing up the improvement work done at this time, and by referring again to the ratings of those new switches installed and also to the short-circuit current tabulations, the writer believes you will see that those new switches not only had capacity to meet the severe duty at the time they were installed, but, with other changes will have capacity also for the proposed, ultimate system. The second short-circuit study substantiates this statement.

During this period of improvement work, plant extensions were made that involved, among other things, the installation of the third machine in the South Power House and two (2) 5750-HP, 6600-volt induction motors on the Billet Mill. In both these instances, however, switching equipment of ample rating was installed in the first place.

A By-Product Coke Plant was installed and put into operation in April, 1926, and as a part of the equipment purchased for this job, a number of truck type switches and a cell-mounted type of line switch, with other necessary equipment, was purchased for the Rectangular Coke Oven Department. This was another step in line with our improvement program. Switching equipment for the new By-Product Plant was based on ratings that also lined up with work done as a result of our short-circuit study.

The Rectangular Coke Oven Department substation contained a 500-KW M-G set and four (4) 500-KVA transformers; one (1) a spare. The old switching equipment was the same as originally installed in other places; 300-ampere oil switches mounted in the open, manually operated, and connected to bare, copper tube buses. The 6600-volt line was originally of the radial type from the South Power House, therefore no new line work was necessary.

A concrete cell was installed for disconnects and line switch with provisions for a bus and another line switch at some future time. Truck type breakers with bus compartments were installed in line with the cell work; three trucks for the M-G set and compensator, and one truck for the transformers which, as a part of the same job, were moved to the outside under a roof. The station thus became quite thoroughly modernized.

Considerable trouble had been expeirenced here in the past with men not so thoroughly familiar with handling manually operated switching equipment connected with M-G sets, in manipulating the switches, The new switches electrically operated and interlocked against certain improper sequence, eliminated such troubles and in this respect alone has proven to be a worth-while improvement.

Our high tension switching equipment program continued; it was accelerated somewhat by the By-Product Coke Plant installation in that North Power House switches were all in use and more switching equipment was needed for two circuits to the By-Product Plant. Rather than undertake the installation of up-to-date switch gear in the North Power House and make it line up with an existing but inadequate plant, it was decided to erect a switch house, or tower, just outside the Power House. It was further decided to connect all trunk or through circuits to this switch tower, through high rupturing capacity breakers, to a bus which, in turn, would be

connected to the North Power House bus through two (2) tie cables and a set of reactors.

In August, 1925, the erection of such a switch tower was authorized.

Fig. 3. North Mill Switch Tower

Designs were made that finally resulted in a structure which is at present one-third the ultimate size, has two (2) trunk line switches and five (5) feeder switches, one set of 7%-1200 amp reactors between it and North Power House bus, a single bus and line disconnecting switches. Provisions were made for extending the building in either direction along axis of the bus. Provisions were also made, and much of the construction work done, so that feeder reactors may be installed when needed; also for another bus, in double bus arrangement, and for the seven (7) switches on the second bus.

If original ideas and designs are ever carried out, forty-two (42) switches, or twenty-one (21) circuits in double-bus arrangement, may ultimately be housed in the one switch house.

Due to a desire to occupy as small an area of ground as possible, it was decided to use a vertical arrangement of isolated phase bus and switch equipment. The three (3) busses with corresponding switch units are therefore on the first three floors, the operating mechanisms are on the fourth floor, and the line disconnects, with provisions for a control board, are on the uppermost floor. Lightning arresters, lightning arrester disconnects and dead-end equipment are on the roof, which is flat.

All feeder circuits were subsequently rearranged at the north end so that circuits from the new switch house feed each one of the five major units, namely: Bar, Billet and 10-inch Mills, Central Pumping Station, and By-Product Plant. A second circuit, for stand-by purposes, to each one of these five places radiates from the North Power House bus.

The switch house is also the north terminus of the two (2) trunk lines from the South Power House, and in this way protects the lower rupturing capacity switches in the North Power House. This arrangement is all shown in schematic on print V-959.

Normal operating conditions at the north end are: Bar, Billet and 10-inch Mills, one-half (½) the Central Pumping Station, and the By-Product Coke Department substation feeding from the North Switch House; the other half of the Central Pumping Station, the Sintering Plant substation, two (2) 1000-KW M-G sets in North Power House and a bank of power transformers feeding from the North Power House bus. All other circuits shown are held in readiness as stand-by feeders. The oil switches installed in this switch tower are General Electric Company make, type FHK 230-20 B, having a rupturing and thermal capacity of 60,000 amperes. The reactors between this switch house and the North Power House bus are also General Electric Company make, and have a reactance of 7 per cent at 1200 amp. These rupturing and thermal capacities seem to be ample for the ultimate, assumed plant, and the tie cable reactors materially lessen the duty on the North Power House switching equipment.

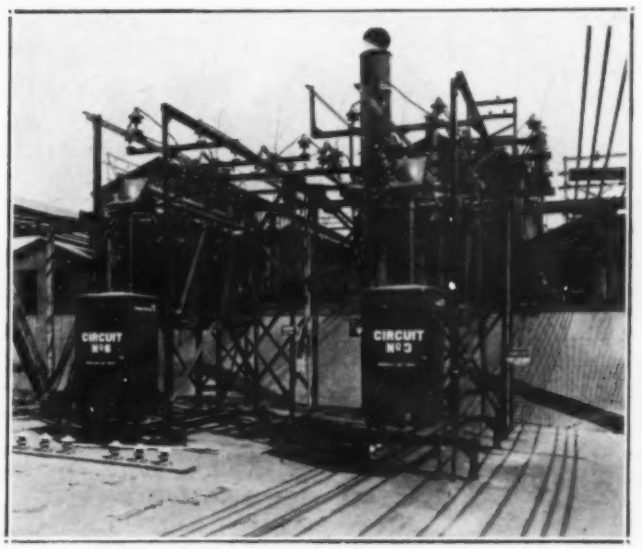


Fig. 4.—Rod Mill Switch Equipment

Another improvement was made in 1926 when two (2) of the four (4) through tie lines were sectionalized and made into radial type feeders. These circuits were sectionalized by installing four (4) pole-top switches. Two (2) such switches were installed in each of the two (2) tie lines and so placed either side the Welded Tube Mill taps, that the Welded Tube Mill and the street railway substation may receive power over either one of two (2) feeders radiating from each power house. These two (2) circuits may also be used as trunk or through tie lines merely by closing the sectionalizing switches.

No particular study has been made of the beneficial effects the sectionalizing of these two (2) cir-

cuits would produce. In both the first and second short-circuit studies, these circuits were treated as through tie lines. It may readily be seen that the number of parallel paths between the two (2) power houses are cut in half and that four (4) substations get the benefits of radial type feeders, all of which would obviously reduce the duty requirements of all switches connected thereto.

Improvements, in line with this same program, were undertaken again in 1927 and two (2) high rupturing capacity breakers were purchased for the Rod Mill substation. It seemed desirable to install adequate switching equipment as quickly and economically as possible, once the work was started, and with a minimum amount of disturbance to substation service. There was not a great amount of room inside the substation for new work, so, in view of all such things, it was decided to install switching equipment on the roof. Out-door equipment was installed as you see it in the picture herewith shown as Fig. 4.

The switches are General Electric Company make, Type FHKO-139-50C-Y, 1200-ampere, 15,000-volt rating with 25,000-volt bushings. The rupturing and thermal capacities are 60,000 amperes.

This was a place where any disturbance on the system would invariably cause trouble and damage. Many are the times when one switch tank, or both, had been partly blown off and aggravated the power disturbance and caused hours delay to finishing department production.

A bad condition was improved materially with the installation of the two (2) line switches on the roof and the way is now open to carry on further improvements inside the substation, and also make this a secondary distributing point for some main motor drives that may be installed eventually in the immediate vicinity. The matter of further improving conditions inside the substation is before us at the present time.

Improvements along our high tension power system were not confined to switching equipment and rearrangements of circuits alone, but comprised lightning arrester changes, cable terminal changes, and replacement and interlocking of nearly all knife-blade type disconnecting switches.

In practically all stations and substations, prior to 1924, at the latest, electrolytic lightning arresters were used and were mounted inside at most convenient places, but not always in the most efficient way. Considerable care had to be exercised in keeping them in good condition and renewal of parts was costly at times. With the exception of two (2) or three (3) electrolytic lightning arresters still in service at the South Power House, all arresters are now of the oxide film, pellet or auto-valve type, mounted out-of-doors, and connected to the line through disconnecting devices. Our experiences to date with these new arresters have been satisfactory and we believe they have been effective in reducing line disturbances.

Cable terminals of the kind and rating originally installed in many places were either the source of some troubles and disturbances originating elsewhere or became involved in them. Many cable terminals, especially those installed out-doors, failed, were completely destroyed, and caused considerable delay to production. These terminals were of 7500-volt rating, working voltage, and in the case of the 3-phase terminals, the distances between phases were 5 inches to 6 inches. The majority of failures were in 3-phase terminals.

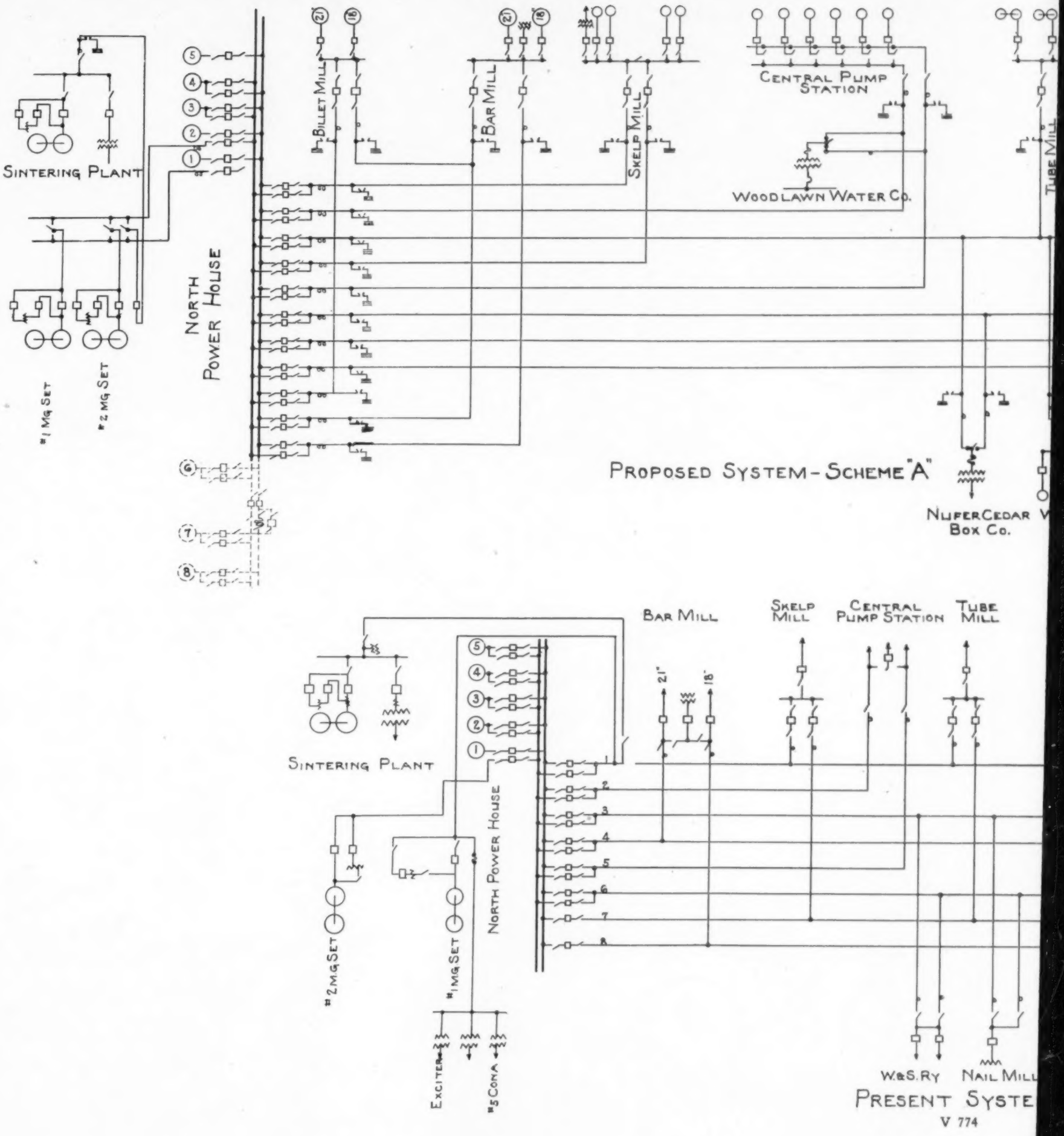
Nearly all cable terminals of such rating, 7500-volt, working potential, have been changed, practically all that were out-doors. Many single phase terminals were used as replacements. These were rated at 25,000 volts but used the same insulators as those 3-phase terminals of 16,000-volt rating. Where the use of 3-phase terminals was continued, a cable terminal of 16,000-volt rating, with a 12-inch spacing between terminal centers, was used. The insulators on these terminals had a rating of 25,000 volts on single phase terminals.

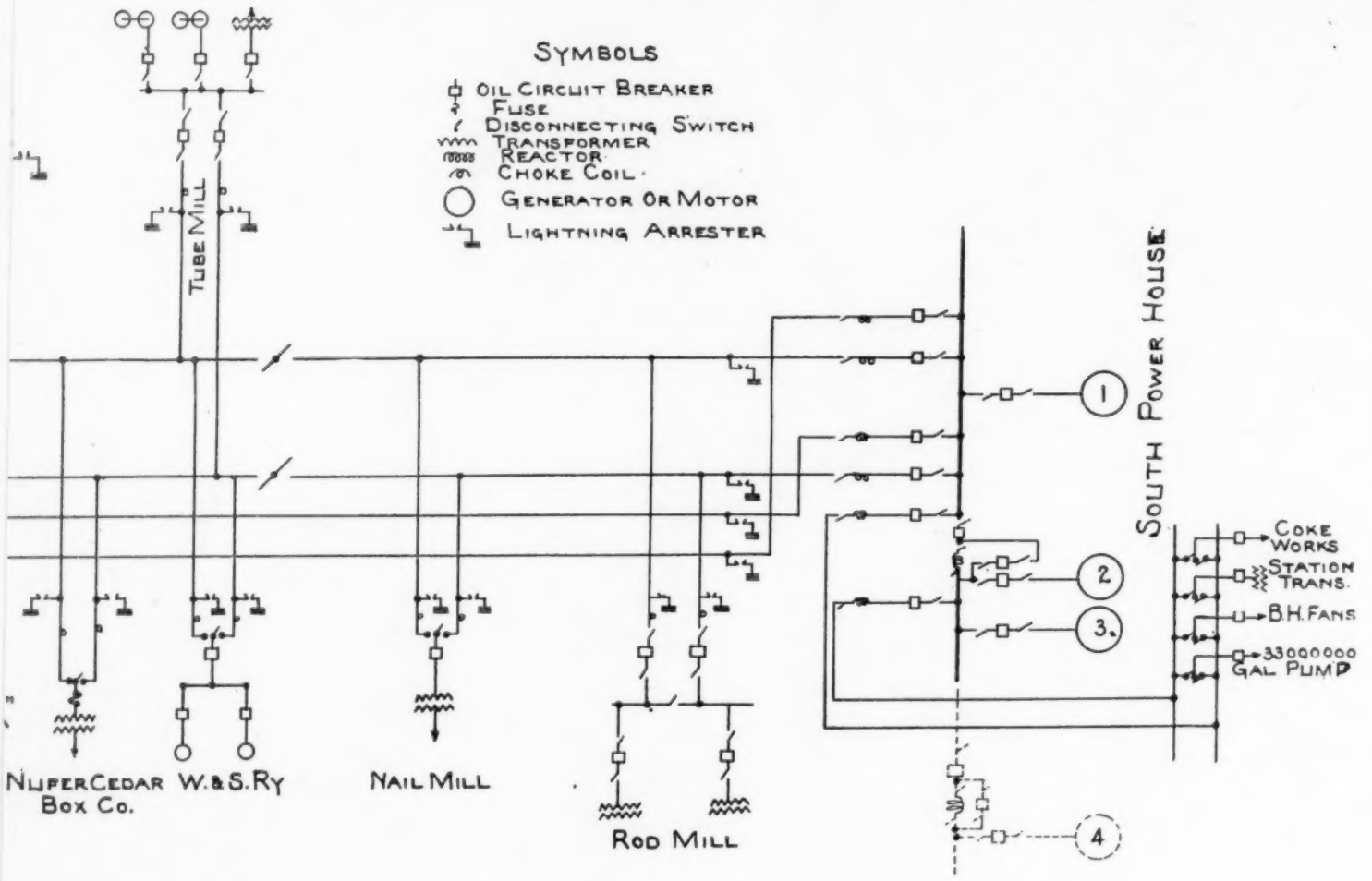
Pin type insulators and dead-end insulators were originally of the 7500-volt class and this equipment went through the same process of improvement, gradually as other improvements were made. Now the system is completely equipped with line insulators suitable, in ordinary clean atmosphere, for a working potential of 27,000 to 30,000 volts, but, in this steel mill atmosphere, good for no more potential than the 6900 to 7000 volts on the bus.

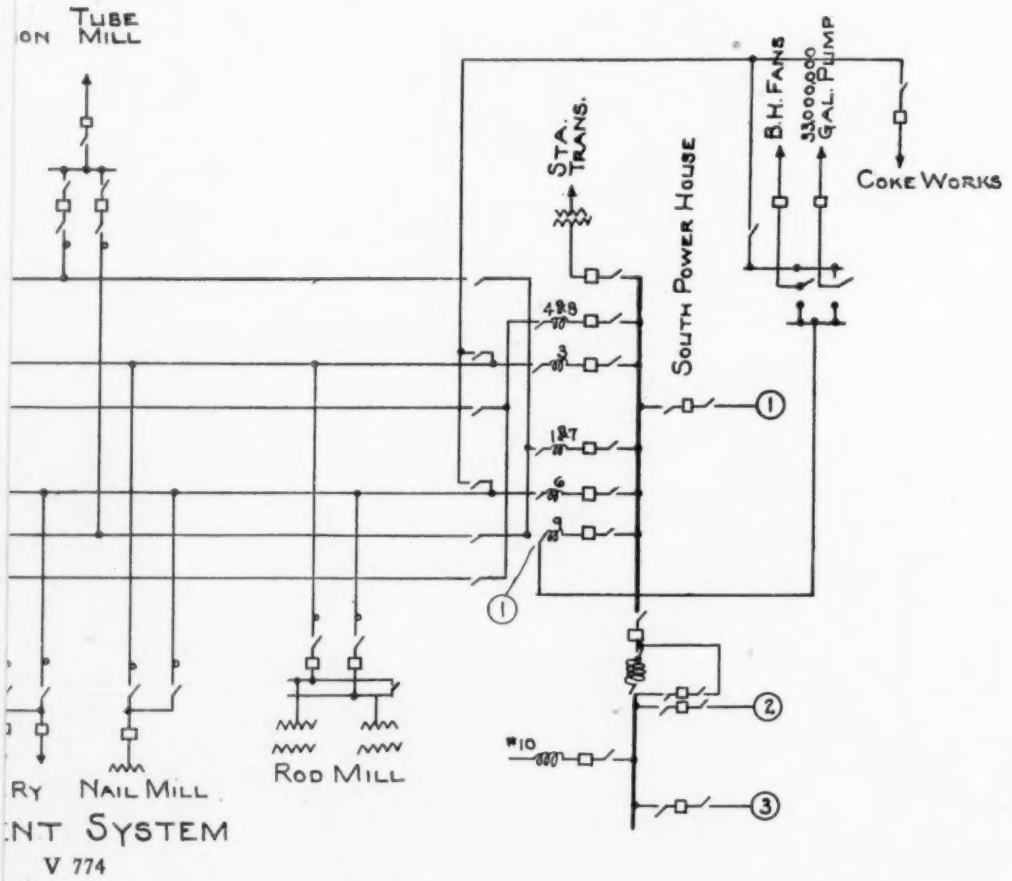
Improved switching equipment, new types of lightning arresters placed out-of-doors at the very end of the aerial cables, higher voltage line and dead-end insulators, cable terminals of much higher voltage ratings and wider spacings, have all in one way or another materially improved operations, prevented failures and break-downs, have made for more continuous operations in the mills and have made a safer condition for operators and maintenance men. We have recently experienced a case of trouble, originating as a flash-over, which in former years would undoubtedly have extended over the entire system, shut every main drive motor down, and caused considerable trouble and damage, was in this instance isolated by three (3) switches clearing one circuit; no other circuits were affected and no main drive motors were shut down. Practically no departments were affected outside the departments supplied with low-voltage power from that substation.

The foregoing is the writers description of improvement work done to date on this 6600-volt power system. Other improvements are under consideration, but none have actually been authorized since that installation on the substation roof. Some rather extensive plant additions have been made in the last two years. These additions involved heavy power demands and two (2) feeders of the radial type were run from the South Power House to the Seamless Tube Plant, where two (2) substations were erected. New electrical equipment was purchased for these plant extensions and you may be sure that care was taken to specify switching equipment that would meet all present and future requirements as for rupturing and thermal capacities.

The line switches for the Seamless Plant substation are General Electric make, type FH-206, 1200 amperes, 15,000 volts with a rupturing capacity of 40,000 amperes and a thermal capacity of 100,000 amperes. The truck type switches through which power to M-G sets, main drive motors, air compressors, and a transformer bank is controlled, are General Electric Company make and are rated 800 amperes, 15,000 volts, with a rupturing capacity of 5300 amperes and a thermal capacity of 40,000 amperes. Under instantaneously heavy currents, relays

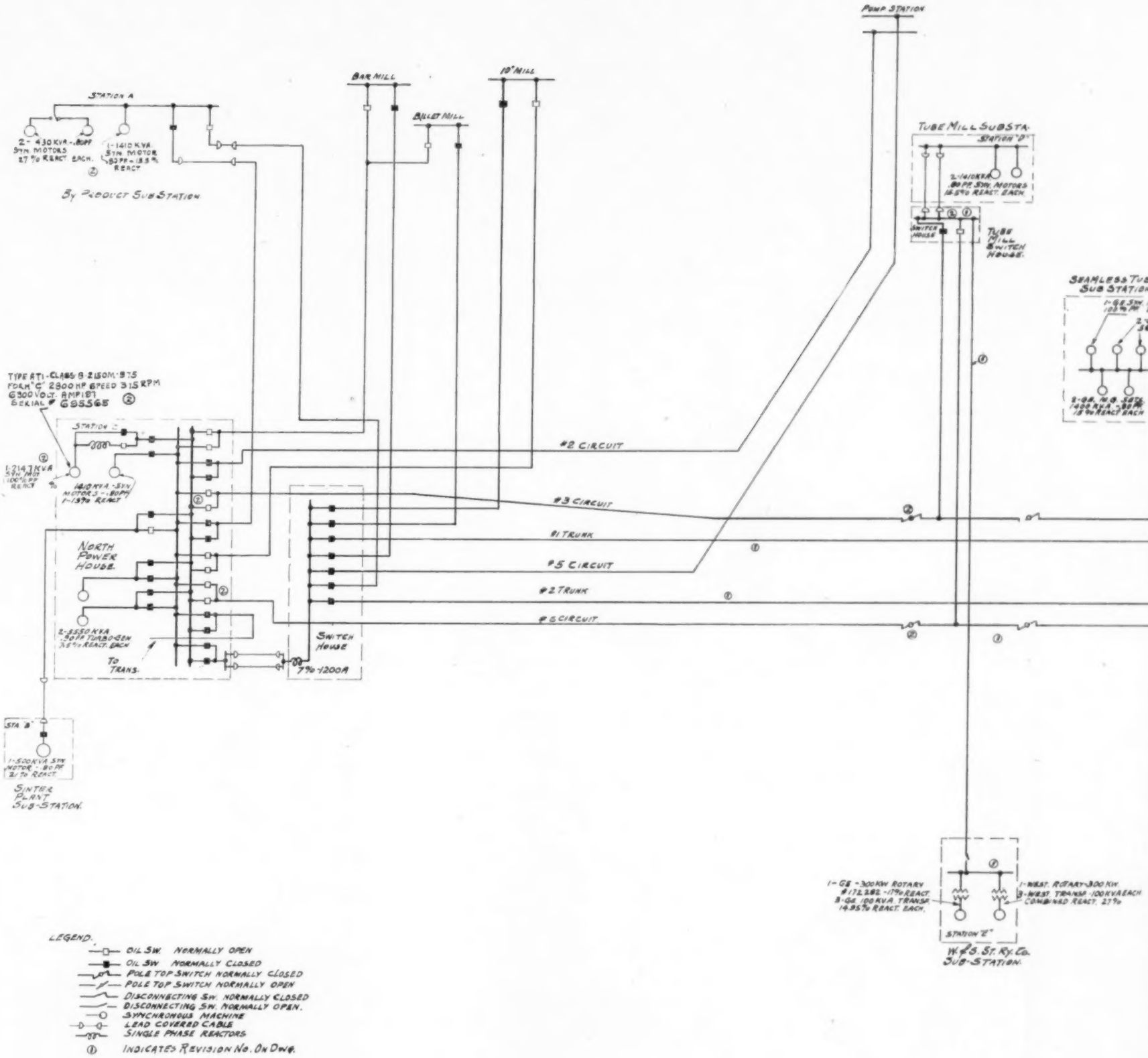

SINTERING PLANT
#1 MG SET
#2 MG SET
NORTH POWER HOUSE
BILLET MILL
BAR MILL
SKELP MILL
CENTRAL PUMP STATION
WOODLAWN WATER CO.
TUBE MILL
NUFER CEDAR V
BOX CO.
PROPOSED SYSTEM - SCHEME "A"
BAR MILL
SKELP MILL
CENTRAL PUMP STATION
TUBE MILL
SINTERING PLANT
#2 M.G. SET
#1 M.G. SET
NORTH POWER HOUSE
EXCITER
#5 CONA
W. & S. RY
NAIL MILL
PRESENT SYSTE
V 774

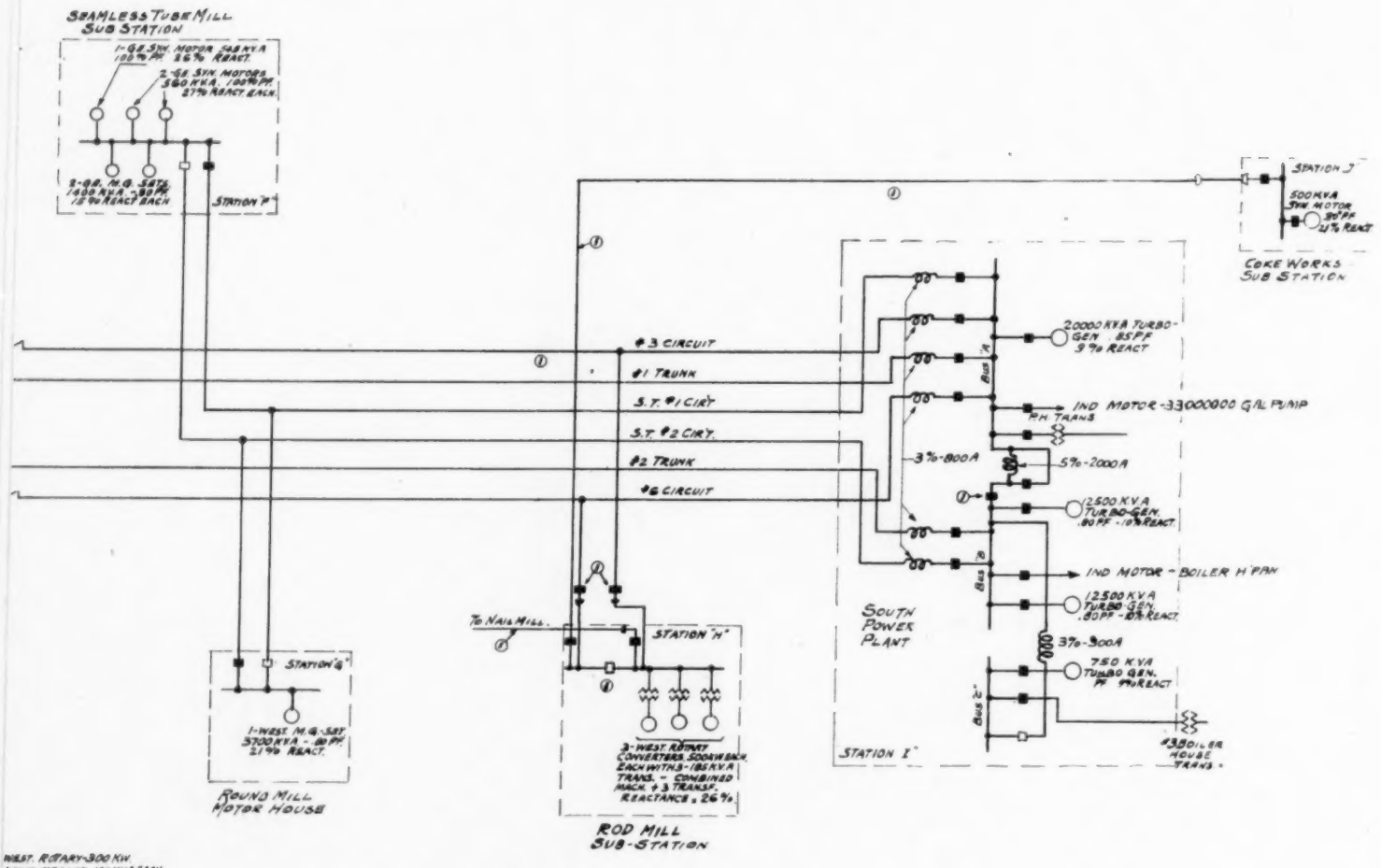




NT SYSTEM

V 774


STATION A
2 - 430 KVA - 80PP SYN. MOTORS 27% REACT. EACH.
1-1410 KVA SYN. MOTOR 180 PP - 18.5% REACT
BY PRODUCT SUB STATION
BAR MILL
BILLET MILL
10" MILL
PUMP STATION
TUBE MILL SUBSTA.
STATION "D"
2-1410 KVA 80 PP SYN. MOTORS 18.5% REACT. EACH
SWITCH HOUSE
TUBE MILL SWITCH HOUSE.
SEAMLESS TUBE MILL SUB STATION
TYPE AT1 - CLASS B 2150M-975 FORM "C" 2300 HP 6 SPEED 315 RPM 6300 VOLT. AMPIBT SERIAL # 695565
STATION C
1214 KVA SYN MOT 100% PF REACT
1410 KVA - SYN MOTORS 3 - 80PP 1-13% REACT
#2 CIRCUIT
#3 CIRCUIT
#1 TRUNK
#5 CIRCUIT
#2 TRUNK
#6 CIRCUIT
NORTH POWER HOUSE.
2-8350 KVA 80 PP TURBO-GEN 26% REACT. EACH
TO TRANS.
SWITCH HOUSE
7% - 1200A
STA "B"
1-500 KVA SYN MOTOR - 80 PP 2% REACT.
SINTER PLANT SUB-STATION.
1-GE - 300 KW ROTARY #172,282 - 17% REACT.
3-GE. 100 KVA TRANSF. 14.95% REACT. EACH.
1-WEST. ROTARY - 300 KW.
3-WEST. TRANSF. 100 KVA EACH COMBINED REACT. 27%
STATION "E"
W. & S. ST. RY. CO. SUB-STATION.
LEGEND.
OIL SW. NORMALLY OPEN
OIL SW. NORMALLY CLOSED
POLE TOP SWITCH NORMALLY CLOSED
POLE TOP SWITCH NORMALLY OPEN
DISCONNECTING SW. NORMALLY CLOSED
DISCONNECTING SW. NORMALLY OPEN.
SYNCHRONOUS MACHINE
LEAD COVERED CABLE
SINGLE PHASE REACTORS
① INDICATES REVISION No. ON DWG.


SEAMLESS TUBE MILL SUB STATION
1-GE SYN. MOTOR 245 KV A 100% PF 26% REACT.
2-GE SYN MOTORS 360 KV A, 100% PF 27% REACT. EACH.
2-GE, M.G. SETS 1400 KW - 80 PF 18% REACT EACH
STATION "F"
STATION "J"
500 KVA SYN MOTOR 80 PF 21% REACT
COKE WORKS SUB STATION
#3 CIRCUIT
#1 TRUNK
S.T. #1 CIRT.
S.T. #2 CIRT.
#2 TRUNK
#6 CIRCUIT
20000 KVA TURBO-GEN. 85 PF 9% REACT
IND MOTOR - 33000000 G/L PUMP
PH. TRANS.
3%-800A
5%-2000A
2500 KVA TURBO-GEN. 80 PF - 10% REACT.
IND MOTOR - BOILER H. FAN
2500 KVA TURBO GEN. 80 PF - 8% REACT.
3%-900A
750 KVA TURBO GEN. PF 5% REACT.
#3 BOILER HOUSE TRANS.
Bus 1
Bus 2
SOUTH POWER PLANT
STATION "I"
To NAIL MILL
STATION "H"
3-WEST. ROTARY CONVERTERS, 500 KW EACH, EACH WITH 3-185 KV A TRANS. - COMBINED MACH. & TRANSF. REACTANCE = 26%
ROD MILL SUB-STATION
STATION "G"
1-WEST. M.G. SET 3700 KV A - 80 PF 21% REACT.
ROUND MILL MOTOR HOUSE

WEST. ROTARY-300 KW
WEST. TRANSF.-100 KV A EACH
COMBINED REACT. 27%

NOTE:
REFER TO MAP 77 FOR ALL PERTINENT DATA
THIS SKETCH SHOWS ONLY SCHEMATIC, SINGLE LINE DIAGRAMS AND SYN. MACHINE RATINGS.
REFER TO MAP 77 FOR PHYSICAL ARRANGEMENTS.

function to lock-in the truck breakers and cause the F.H. line breakers to open. This installation was not contemplated at time of the first short-circuit study, but were in the second study. Figures obtained in the second study show that these switches are of ample capacity under all practical conditions.

A 30" reversing mill for rolling rounds for the Seamless Plant was also a part of the initial Seamless Plant unit. The Round Mill substation contained two (2) line switches installed in concrete cell work, a truck type switch group for the M-G set and transformer bank and the M-G set and reversing mill motor. The station receives power over two (2) circuits tapped onto those which feed the Seamless Plant substation.

Line switches in this case are Westinghouse O-22, 1200-ampere, 15,000-volt rating with a rupturing capacity of 57,500 amperes and a thermal capacity of 100,000 amperes. The truck type breakers are also Westinghouse make, type B-13, 1200 amperes, 15,000 volts with a rupturing capacity of 5800 amperes and a thermal capacity of 40,000 amperes. Here, again, relays are installed to lock-in the truck breakers and make the line switches rupture currents beyond the rating of the truck breakers.

(6) Description of Changes Made in Power System Characteristics, 1923-1927, Inclusive, and Compilation of New Data

During all the years this revamping work was being done, more particularly during the last two years, the size, shape, and lengths of our transmission lines were being changed, wider spacings and longer spans in some instances were used, and in general the characteristics of the entire power transmission system were materially changed, especially when compared to those on which the first short-circuit study was started.

The trunk or through lines for a great part of the distance were carried on wood poles set in temporary locations. It was necessary, from time to time, to change these locations to clear ground for some new project. As buildings and permanent structures along the line of proposed permanent location of the lines were erected, the lines were changed to these buildings or structures and thus became more permanently located. Towers, over one hundred (100) feet tall, were erected in several places to span ground on which no buildings had yet been erected, so that lines could be more permanently located and yet permit of building work underneath later on. The second unit of the Seamless Plant was actually erected under the power lines and adequate service over some of those power lines was maintained at all times. The power lines now are in what seems to be a permanent location.

In making these changes it was found to be less costly, if, instead of moving four (4) 4/0 circuits which had been connected at the ends to form the two (2) trunk lines, two (2) new circuits of 600,000 cm cable were installed. This change not only reduced the amount of insulators and line hardware necessary, but increased line capacity considerably and, of course, by 50 per cent the amount of through line we had to maintain.

It was deemed advisable to use wider spacings on new work because longer spans were used and the heavier copper was suspended by suspension type insulators rather than being tied to pin-type insulators, consequently that part of the aerial system which has been changed and improved in the last two years uses a 42-inch triangular spacing. There is still some 28-inch spacing, but it is in that part of the line which has not been touched lately. Some 36-inch spacing was used, principally because a 42-inch spacing could not easily be made.

Descriptions in detail of the various changes made in the power system may not be of interest here. A description of improvement work done is also that of changes made during the same time. By referring to drawing V-774, "Present System," and to V-959, one type of changes in particular will be noted; a change in connections. The many paths for currents to flow in the older system become fewer in number and more sectionalized in the new system, and, too, the newer system seems simpler.

Since the first short-circuit study was made, a third turbo-generator of 12,500-KVA capacity was actually installed at the South Power House and several pieces of synchronous equipment were also installed.

A large sum of money had been spent and much work done on new switching equipment and in otherwise improving the power system, and a much larger power system was in prospect.

In view of these changes and additions, and with a desire to check the first short-circuit study and the work done to date, also for further guidance when it became necessary to install another turbo-generator, the idea of a second study was conceived early last year. Consequently, complete new lists of reactance values were obtained from the various manufacturers, a new single-line, schematic diagram of the system was made and a larger drawing showing spans, spacings, lengths of lines, relative locations and all stations and substations, with descriptions of all synchronous equipment used, was made. The schematic diagram is shown as Drawing V-959, and the larger drawing as Map 77. Map 77 is rather a disorderly arrangement of all kinds of data, but it is quite complete.

These drawings and data were given to the General Electric Company and a study of short-circuit currents, based on such data, was made in June, 1928.

(7) Description of Second Short-Circuit Study

The purpose of this study, as outlined in a report of that study, was to determine if any of the present breakers would have their interrupting or short time current carrying capacity exceeded on short circuit after the addition of a new 20,000-KVA generator at the South Power House. There was another purpose in view; checking the revamping work done on the system, especially since many of the line characteristics had been changed and many new switches installed. Also to compare new figures with those obtained in previous study.

Certain assumptions were necessarily made as to added capacity, location, etc.

It was assumed that an additional machine of 20,000-KVA capacity would be installed at the South Power House and would be connected to its own bus which would be connected to the existing bus through a reactor having 5% reactance at 1750 amperes.

It was also assumed that there would be no

further increase in synchronous motor load and that the pole top switches in circuits #3 and #6 would be closed to provide additional trunk line capacity.

The schematic diagram, V-959, showed the 5%-2000 ampere reactor normally shorted in the South Power House bus, so it was decided that readings would be taken for two (2) conditions, one with reactors shorted, the other with reactors in service with the shorting breaker open.

Practically all motor rooms and substations, served by two (2) feeders, normally operate with only one circuit-breaker closed, the breaker on the second feeder being open. A few trials in the calculating and test work showed that changing from one feeder to the other made very little difference in the total short current to any of the worst short circuit points.

A study was made at this time of voltage conditions at various points during a short circuit condition at some selected point.

"Whether or not a synchronous machine will stay in synchronism during a short circuit on some other part of the system depends upon the constants of the machine itself, its terminal voltage maintained during short circuit, duration of the voltage dip, etc.

"Of these factors, only the voltage at the machine terminals is readily obtainable for the various short circuit conditions. From calculations 60% of normal voltage has been chosen as a value above which the machine can be expected to stay in synchronism and gives a basis for estimating the effect of a short circuit on machines remote from the point of short circuit."

The report made of that study comprised tabulations as follows:

Table No. 1. Location of short, O.C.B. type and number referred to a single line diagram used for calculations and test, maximum current to be interrupted and instantaneous unsymmetrical current, all for those operating conditions when the South Power House bus reactor was in service (reactor shorting switch open).

Table No. 2. Included figures under same heading, but for operations when the bus reactor at South Power House is shorted.

Table No. 3. Showed points at which voltages dropped below 60% corresponding to those conditions used for Table No. 1, and Table No. 4 showed the same things corresponding to those conditions used for Table No. 2.

Table No. 5 and Table No. 6. Showed points where voltages were below 50% and above 70% and also the calculated intermediate values corresponding with tables No. 1 and No. 2 respectively.

(8) Resume of Second Short-Circuit Report and Conclusions Drawn Therefrom

In looking over that report we note that when the South Power House bus reactor is in service the rupturing capacity of none of the breakers is exceeded by possible short-circuit current values. In four (4) cases, however, instantaneous unsymmetrical current values exceed the one (1) second capacity of four (4) breakers, excesses varying from 120% to 142% the (1) second capacities. These four (4) switches may be changed so that sufficient one (1) second capacities will obtain. Several switches have already been changed by obtaining certain new parts from the factory.

These South Power House switches, whose one (1) second capacities do not measure up to duty requirements as shown in the short-circuit study report, were among the early installations and were not, in anyway, involved in the revamping work done during the last six (6) years.

If the South Power House bus reactor is shorted and a short-circuit should occur in any one of a number of places at the South Power House, then the rupturing capacity of two (2) switches will be exceeded, and in the case of five (5) switches the one (1) second capacity will be exceeded. There seem to be no changes, of a practical nature, that can be made to alleviate these conditions, and it is therefore concluded that the bus reactor should always be left in the circuit.

A further study of the report shows that neither the rupturing nor one (1) second current capacity of any of those breakers installed during the revamping work will be exceeded by any short circuit current that showed up in tests or in calculations. We conclude from this that the switches used in this work and installed in various motor rooms, sub-stations and switch houses will satisfactorily meet all duty requirements with at least 20,000 KVA more generator capacity added to the system.

It is interesting to note that the severest duty requirements will not be imposed on the generator switches in the South Power House, but on a 525-HP induction motor circuit without reactor connected to that section of bus shown as Bus B, drawing V-959. The next severest duty may be required of that switch connecting Seamless Tube No. 2 circuit to Section "B" bus, referred also to V-959; this only in case the short circuit should occur between the circuit breaker and the reactor. This fact in itself teaches us to pay particular attention to the type of construction and class of material we would use between circuit breaker and reactor to eliminate the possibility of a short circuit between such two pieces of equipment.

Several tables showing voltage conditions at various points in the system during short-circuits, as observed or calculated during tests, may be of interest to those who will examine this paper more in detail, and these tables are therefore set down below:

TABLE No. 3—SOUTH POWER HOUSE BUS REACTOR IN SERVICE

Short at	Voltages below 60% at
N.P.H. Bus	N.P.H. Sw.Sta., Sta. A, B, D, E, H, & J
S.P.H. Bus #2	All points except S.P.H. Bus #4
S.P.H. Bus #3	All points except N.P.H., Sta. A & B
S.P.H. Bus #4	S.P.H. Buses #3 & #4
Station A or B	N.P.H., Sta. A, B, D, & E
" D	N.P.H., Sta. A, B, D, E, & J
" E	N.P.H., Sta. A, B, D, E, & H
" F	Sta. F
" G	Sta. G
" H	Sta. H & E
" J	Sta. J
Sw. Station Bus	Sw.Sta., N.P.H., Sta. A, B, & E
Pumping Sta.	Sw.Sta.
Skelp Mill	Sw.Sta.,N.P.H., Sta. A, & B

TABLE No. 4—SOUTH POWER HOUSE BUS REACTOR SHORTED

Short at	Voltages below 60% at
N.P.H. Bus	N.P.H., Sw.Sta., Sta. A, B, D, E, H, & J
S.P.H. Bus #2 or #3	All station
S.P.H. Bus #4	S.P.H., Bus #4
Station A or B	N.P.H., Stations A, B, D, & E
" D	N.P.H., Stations A, B, D, E, & J
" E	N.P.H., Stations A, B, D, E, & H
" F	Station F
" G	Station G
" H	Station H, & E
" J	Station J
Sw. Sta. Bus	Sw.Sta., N.P.H., Stations A, & B
Pumping Sta.	Sw.Sta.
Skelp Mill	Sw.Sta., N.P.H., Stations A, & B

TABLE NO. 5—SOUTH POWER HOUSE BUS REACTOR IN SERVICE

	Percent Voltage at Station										
	Sw. Sta. Bus	Sta. A or B	N.P.H.	D.	E	F	G	H	S.P.H. Bus #2(B)	S.P.H. Bus #3(A)	S.P.H. Bus #4(New)	Sta. J.
N.P.H. Bus	O	O	*	O	O	X	X	O	69	X	X	53
S.P.H. Bus #2(B)	O	48	48	O	O	O	52	O	*	O	66	O
S.P.H. Bus #3(A)	O	61	61	58	56	O	O	O	O	*	O	O
S.P.H. Bus #4	X	X	X	X	X	X	62	X	X	56	*	X
Station A or B	62	*	O	51	52	X	X	X	X	X	X	X
Station D	61	O	O	*	51	X	X	63	X	X	X	50
Station E	63	48	48	56	*	X	X	O	X	X	X	69
Station F	X	X	X	X	X	*	X	X	77	X	X	X
Station G	X	X	X	X	X	X	*	X	78.5	X	X	X
Station H	69	65	65	66	O	X	X	*	68	X	X	X
Station J	X	X	X	X	63	X	X	X	73	X	X	*
Sw. Sta. Bus	*	54	54	60	59	X	67	X	X	X	X	68
Pumping Sta. (Normal)	46	64	64	X	X	X	X	X	X	X	X	X
Skelp Mill (Normal)	13	59	59	X	X	X	X	X	X	X	X	X

TABLE NO. 6—SOUTH POWER HOUSE BUS REACTOR SHORTED

N.P.H. Bus	O	O	*	O	O	X	X	51	X	X	X	56
S.P.H. Bus #2(B) or #3(A)	O	O	43	O	O	O	O	O	*	*	O	O
S.P.H. Bus #4	X	X	X	X	X	68	67	68	62	62	*	67
Station A or B	62	*	O	53	53	X	X	X	X	X	X	X
Station D	62	O	O	*	55	X	X	70	X	X	X	53
Station E	63	49	49	57	*	X	X	O	X	X	X	X
Station F	X	X	X	X	X	*	X	X	81	81	X	X
Station G	X	X	X	X	X	X	*	X	83	83	X	X
Station H	68	66	66	68	O	X	X	*	X	X	X	X
Station J	X	X	X	X	63	X	X	X	X	X	X	*
Sw. Sta. Bus	*	54	54	60	60	X	X	69	X	X	X	X
Pumping Sta. (Normal)	46	64	64	X	X	X	X	X	X	X	X	X
Skelp Mill (Normal)	13	59	59	X	X	X	X	X	X	X	X	X

(*) Short circuit point.
(O) Below 50% voltage.
(X) Above 70% voltage.

A more careful perusal of the report made of the short-circuit study in June, 1928, may reveal more useful facts; those described above, however, are of the high spots.

A tabulation showing the rupturing and one (1) second and five (5) second current capacities of various breakers is submitted herewith as a part of this paper. The values in that tabulation were obtained either from manufacturer's catalogs or from district office engineers and are, of course, subject to changes or corrections by the respective manufacturers.

OIL CIRCUIT BREAKERS

Location	No.	Mfr.	Type	Rating Amps	Rating Volts	Amp. Rupt. Cap. 7500 V	Amp. Rupt. Cap. 6600 V	Therm. Cap. at 7500 V 1 Sec.	Therm. Cap. at 7500 V 5 Sec.	Remarks
Coke Works	1	G.E.	FH-203	1200	7500	32000	36400	80000	60000	
Substation	4	G.E.	FK-132B	800	15000	5300	6000	40000	40000	
Rod Mill	2	G.E.	FHKO-139-50-CY	1200	15000	60000	68300	60000	60000	
Substation	2	G.E.	FK-12	800	15000	2300	2620	35000	35000	
	1	Whse.	B	600	6600					
South Power	3	G.E.	FH-3	800	15000	11400	26000	60000	40000	
House	1	"	FH-203	1200	7500	32000	36400	80000	60000	Tanks and Contacts changed to FH-203 7500 volt.
	1	"	FH-3	800	15000	11400	26000	60000	40000	
	2	"	FH-203	800	15000	28000	31800	60000	40000	
	3	"	FH-206	800	15000	40000	45500	80000	40000	
	2	"	FH-206	1200	7500	46000	52300	100000	60000	
	2	"	FH-206	2000	15000	40000	45500	100000	100000	
	1	"	FH-6	3000	15000	28000	31800	100000	100000	
	1	"	FH-6	1200	15000	28000	31800	100000	60000	No. 3 Gen.
	1	"	FH-206	1200	15000	40000	45500	100000	60000	No. 2 Gen.
Welded Tube Mill	8	Whse.	B-13	1350	15000	5800	6600	40000	40000	
Central	6	G.E.	FH-103	500	15000	23000	26200	40000	25000	
Pump House	1	"	FH-203	500	7500	32000	36400	40000	25000	
Switch House (Tube Mill)	2	Whse.	OE-6	750	15000	32000	36400	40000	30000	Style 2-D 497
10" Skelp	2	Whse.	OE-6	750	15000	32000	36400	40000	30000	
Mill	10	"	B-13	1350	15000	5800	6600	40000	40000	Style 2-D 495
Billet Mill	2	G.E.	FK-132B	800	15000	5300	6000	40000	40000	
Motor Room	2	"	FH-206	800	15000	40000	45500	80000	40000	
Bar Mill	2	G.E.	FK-132B	800	15000	5300	6000	40000	40000	
Motor Room	2	"	FH-6	800	15000	28000	31800	80000	40000	
North Mills Switch Twr.	7	G.E.	FHK-130B	1200	15000	60000	68200	60000	60000	
North Mills	1	Condit	F-11A	800	15000					Serial No. 186269
Power House	6	Whse.	C	600	6600					
	17	"	C	600	13000					
By-Product	2	G.E.	FH-206	800	7500	46000	52300	80000	40000	
Substation	11	"	FKR-132B	400	15000	5300	6000	40000	20000	
Sintering Plant	4	Whse.	B-13	1350	15000	5800	6600	40000	40000	
S.T. #2 & #3	2	G.E.	FH-206	1200	15000	40000	45500	100000	60000	
Substation	25	"	FKR-132B	800	15000	5300	6000	40000	40000	
30" Round	2	Whse.	O-22	1200	15000	57500	65400	100000	60000	
Mill	4	"	B-13	1200	15000	5800	6600	40000	40000	

(9) Description of Power Transmission System Layout at Present

The system as it exists today has been described, in a way, in the descriptions of the improvement work done to date and the work done in preparing data and information for a second study of short-circuit currents.

The system comprises two (2) power plants with a total generator capacity of 56,000 KVA (47,000 KW), nine (9) substations, and four (4) switch houses for main drive motor groups.

Two (2) 600,000 c.m. trunk lines, so called, connect the two power houses. Two (2) other circuits parallel these trunk lines, but these ordinarily serve as feeders for five (5) substations. They can be connected straight through by closing pole top switches whenever additional trunk line capacity is needed. The other four (4) substations and the four (4) main drive motor groups are fed over radial type feeders from either one power house or the other.

All lightning arresters, with exception of two (2) or three (3) of the electrolytic type, are mounted out-of-doors as close to the dead-end structures as possible.

Out-door insulators are rated 16,000 volts working potential for the 3-phase cable terminals, and 25,000 volts, or better, for single-phase terminals, line and dead-end insulators.

Line disconnects are mostly gang-operated and interlocked against opening while under load.

Circuits are now so arranged and of sufficient capacity that it is not necessary to operate any in parallel or interconnected, except the two trunk lines which are, of course, connected at either end to a common bus.

No overhead ground wires are used, neither is a grounded neutral used, but provisions have been made for both.

The aerial lines are carried on structural steel supports mounted on roofs and other building structures wherever possible; to the extent that more than half the lines are so located in what seem to be permanent locations and out of reach of locomotive cranes.

New switches have replaced nearly all the low rupturing capacity breakers and improvements otherwise made, except in three places already under active consideration, until now the switches should withstand all the currents that will likely develop in case of short circuit anywhere. Also with other improvements that may yet be made, more generator capacity may be installed and yet not create conditions that will cause us to undo, tear down,

or revamp any of the improvement work we have done this far.

The system seems to be nearly in that condition which is entirely satisfactory for present generator capacity and which will permit of additions and further improvements without the necessity of having to tear down and rebuild.

(10) Resume of Power Failures and Trouble Reports Since First Item in Revamping Work Program was Completed in 1924, Up to Present Time

Some early reports in detail are at hand on power failures and troubles experienced with the 6600-volt system, but it was not until 1924 that detailed reports were made for each and every case of trouble which resulted in interruption of service.

The following tabulation will show the number of complete and the number of partial failures by years, 1924 to 1928, inclusive:

1924—11 Complete Failures; 0—Partial Failures.
1925— 5 Complete Failures; 2—Partial Failures.
1926— 8 Complete Failures; 2—Partial Failures.
1927— 4 Complete Failures; 2—Partial Failures.
1928— 2 Complete Failures; 1—Partial Failure.

We mean by "Complete Failure," that service over the entire system was interrupted, and by "Partial Failure," that one or two circuits, or some part of the system, was affected but not the whole system.

In the year 1924 two (2) cases of "Complete Failures" were caused by lead-covered, three-conductor cable shorting (caused by heat), four (4) cases were due to out-door cable terminal failures, two (2) to 6600-volt winding failures, and three (3) other failures were due to as many different causes.

During 1925, two (2) of the five (5) complete power failures were due to lightning, one (1) to a grounded line insulator, one (1) to a locomotive crane running into the lines, and one (1) due to a 22-KV line falling across our 6600-volt lines. Some coils grounding in an M-G set, and a shorted 3-phase lead-covered cable caused power interruptions on local circuits.

There was an increase in power troubles that affected the entire system in 1926; eight (8) complete failures. Two (2) of these were due to cable terminal failures, grounding of two (2) stator coils in an M-G set caused one, a broken cross arm caused one, opening wrong disconnects which were loaded caused one, two (2) were caused by lightning, a locomotive crane caused one, and the cause of the eighth was never definitely determined.

There was a very substantial decrease in power interruptions during 1927; only four (4) complete and two (2) partial interruptions were recorded. Two (2) interruptions were caused by lightning, one by a disconnecting switch flashing to ground when switch was opened with only the exciting current of the transformer flowing, and the fourth one was caused by a locomotive crane. One partial interruption occurred when a laborer struck a pick into a lead-covered cable.

The record of only four (4) failures in 1927 was reduced 50% in 1928 when only two (2) interruptions of power occurred on the system; one due to water running down over some insulators in the leads to one of the generators, and the other to voltage regulator trouble.

In 1927 and 1928, there were no troubles due to cable terminals or insulator failures, or to lightning, although several severe storms passed our way.

We have experienced one disturbance to date (let us hope it is the only one for 1929). It involved only one circuit, however, and caused no damage outside the station wherein the trouble started. A high-tension power fuse blew under too heavy a load and caused a flash-over which, to all appearances, caused a short circuit. The new line switch on the roof functioned as it should, but the power houses circuit breakers on that same circuit also tripped. No other switches opened and none of the rolling mills or major units were affected. Had this same kind of trouble taken place in 1923, or earlier, several of the many 300-ampere oil switches would have been damaged and the entire system would have been without power for some time.

Probably nothing reflects improvement in operations, brought about by improvements throughout the entire 6600-volt system, like the tabulation of power failures by years, noted above. A feeling of security now obtains; that cable terminals are not likely to fail, oil circuit breakers will not blow up, that the chances are good for isolating disturbances and confining them to one circuit, that a standby or second source of supply will not be damaged, and that conditions are nearly right for making extensions without first having to replace inadequate equipment.

(11) Some Probable Considerations for the Future

There is still in prospect a much larger power system. More and larger generators will very likely be added in a few years to come, more circuits will be needed, and new centers of distribution will be created.

At the present moment a new turbo-generator of 20,000 KW capacity or larger is in the picture. This installation will of course mean more switch gear and circuits of some kind, and will have a bearing on operation of present equipment. In the second study of short-circuit currents, it was assumed that this machine would be installed in the South Power House and short-circuit currents were calculated accordingly. Now it seems that this machine may be installed in or near the North Power House, in which event it will have a different bearing on operation of existing equipment. Consequently, a third study of short-circuit currents with this machine in another assumed location is now in prospect.

It seems certain that more reactors will be installed as more generator capacity is added, especially in the North Switch Tower feeder circuits, and also for protecting the North Power House bus and switches.

Not enough attention is yet given to our present relay equipment and as the system grows, not only will more attention have to be paid to these relays, but also to a relay system of much greater scope, with more care given to sequence of operation and to the isolation of circuits and apparatus when trouble occurs.

The matter of a grounded neutral system may well be considered. We know very little of what a grounded neutral system may mean to us, but we will keep an open mind on the subject and be guided by both what others have experienced along this line and what the manufacturer's experts ad-

vise. Such a system may become necessary if we are to make the most of adequate relay protection.

An overhead ground wire was at one time used over all our transmission lines but, due to many changes on account of temporary locations, the ground wires were gradually dispensed with until now no such wires are used. We have operated for several years without them. The lines are now in permanent location and it may be that overhead ground wires should be installed. This is a question for which we have not yet developed an answer.

Transmission of power over the trunk lines at a much higher potential through transformers may come up for serious consideration. The system is comparatively short and so compact that such a change would not prove economical for some time to come.

Automatic substations are being used with satisfactory and economical results, and this particular subject will be carefully considered as new substations are needed.

The use of synchronous motors for main drive applications is becoming more prevalent. These machines are very desirable wherever they can be used, but their performance characteristics during a short-circuit condition must be duly considered and precautionary measures provided.

An isolated production unit is served with 60-cycle, purchased power. As the matter of frequency converter equipment for tying two systems together has been considered before, so may it again come up for consideration. It is rather doubtful, however, that much consideration will ever be given to the installation of 60-cycle power generation equipment because a sizeable 25-cycle, modern system already exists.

In concluding this paper, the writer desires to convey an expression of appreciation to those with whom he is associatde in his work for the help they have given him and also to engineers in both Westinghouse and General Electric Companies.

The writer does not take credit for conceiving the idea of the first short-circuit study. That work was done by a man in our employ at that time as power engineer, with whom the writer worked and whom the writer assisted in such work.

The writer hopes that the paper just presented is replete enough with substantial matter to have proven interesting and worth-while, and that it may prove useful to others.

Discussion

L. A. Terven*: Mr. Hussey's paper is of great interest to the public utilities. The West Penn Power Company has experienced growing pains for several years, and these have been more pronounced since the major generating plants have been connected together.

It is an easy matter for an enterprise to outgrow the rupturing capacity of its breakers before the matter is summarily called to the attention of the engineers by severe equipment failures and consequent interruptions to service. The cures to this condition are well given by Mr. Hussey, and include:

a. Segregation of loads, with automatic cutting of tie lines.
b. Radial or loop feed systems.
c. Reactors at critical points.
d. Larger circuit breakers.
e. Use of a large breaker to protect a group of smaller breakers.

The cures can be made more effective by other methods hinted at by Mr. Hussey, to wit:

a. Effective relaying.
b. Neutral grounding.

Although the number of faults for the last few years is very low, I believe that the installation of an adequate relaying system, including ground relays, would limit the outages to the equipment involved so that no system outage would be experienced.

The flash-overs during trouble on the lines would suggest surging, as is only too common on system with ungrounded neutrals. Arcing grounds with consequent excess voltages are common with isolated neutral systems, especially when the insulators are subjected to atmospheric conditions that are usual around steel mills.

While a dead grounded neutral is the most effective in reducing surge voltages and while it also offers the advantage of requiring no special ground relays, the general practice today is to use a resistance in the neutral which will limit the current to a value sufficient to isolate the fault through the use of ground relays, but insufficient to cause distress on the circuit breakers. Practically all of our shorts originate as a phase to ground fault, and prompt ground relay action will isolate the trouble before a disastrous phase to phase short develops.

We use the five second thermal rating of the breakers, as our relaying is based on selective timing as a rule. By slowing down breaker action we can take advantage of the decay in generator output due to the synchronous reactance of the machines coming into play. Several of our generators have over 100% synchronous reactance. This means that less than full load is supplied to a dead short after the transient effects are past.

The so-called transient reactance usually described as the sum of the armature tooth leakage reactance and the field leakage reactance limits the initial short circuit current. For the first five or six cycles the current also experiences a transient effect which may cause a doubling of the current, due to relations between voltage and future phase of current at the time of the fault. If we set the relays for a slight delay we will permit transient conditions to fade into steady state short circuit conditions which are easier for the breaker to handle. This does not apply to cable failures, which are progressive, and may involve maximum current at the time of breaker opening.

I have been asked to say a word about calculat-

*Technical Engineer, West Penn Power Co., Pittsburgh, Pa.

ing boards. A perfect board would represent all material quantities in a three phase way. Such a board is impracticable to construct because it would involve distributed capacity and inductance for the transmission lines—a difficult thing to install. Such a board would give:

a. Shorts of all kinds, including phase to ground, phase to phase, and three phase.
b. Line regulation and current distribution during operation.

I do not know of any such commercial board, although several experimental boards have been built for laboratory work, where only a few units are required. Even this board will not give full transient data unless imitation generators are in use at generating points.

With the next type of board we neglect resistance and use only reactance. For convenience we use D. C. as a source and then transfer reactance values into resistance. This board permits three phase short circuits to be measured direct and nothing else. Phase to phase short circuits can be measured by using three setups of the resistors, but phase to ground currents involving ground resistance cannot be measured. Line regulation cannot be measured at all.

The last type of board can be made in three ways:

1. Fixed resistors representing lines and apparatus.
2. Variable resistors for the same purpose.
3. A combination of (1) and (2).

The West Penn board uses a 40-volt D. C. source with fixed resistors for present equipment and variable resistors for future apparatus. Arrangements are made so that any line or piece of apparatus may be temporarily retired from the board and a substitution made of other lines, etc.

A. C. Cummins*: The Association is to be congratulated on having a paper, which is so pertinent to safe and reliable operating conditions in steel mills, presented by one so fitted to tell the story as Mr. Hussey. I would like at this time to express my admiration of the way in which Mr. Hussey has presented data in reference to troubles in a frank and courageous way. It therefore behooves those present at this meeting to enter into the discussion in an equally frank and open way, with the idea of having the records of the Association well supplied with data that is absolutely accurate, for the benefit of those who may in the future be required to investigate this interesting subject.

Short circuits on power systems in steel mills, whether such systems are supplied from local generating stations or public utilities should be eliminated as far as possible and those short circuits which will occur, even after all precautions are taken, must be limited in magnitude and in the extent which they affect operations for two reasons, which are as follows:

(1) Short circuits, if not restricted in their magnitude, will cause total interruptions with the resulting loss in production and possible damage to equipment.

(2) Short circuits must be limited in magnitude and be properly controlled to safeguard employees whose duties require their presence in close proximity to electrical apparatus.

My first experience with the solution of short circuit problems was at the Duquesne Plant of the Carnegie Steel Co. in 1916. At that time the power system consisted of several radial feeders, with power supplied by 7,500 KVA in engine type generators, and 18,750 KVA in turbo-generators. The oil switches installed in the power house at that time had adequate rupturing capacity to handle short circuits, but did not possess sufficient mechanical strength or short time heat absorbing capacity to successfully withstand the initial current rush due to short circuits, or the heat developed under such conditions before the breaker could open. Furthermore, voltage conditions in the power house bus were so poor at times of short circuit that all synchronous apparatus dropped out of step and a 100% interruption of service throughout the plant was usually the result of any line trouble or other disturbances. The problem therefore was one of maintaining continuity of service on feeders not directly affected by trouble during times of short circuit and overcoming mechanical heating difficulties rather than preventing the explosion of oil switches or the injury of employees.

After making studies of the various methods which could be used to solve this problem, feeder reactors were decided upon because they would limit the short circuits to values for which the existing circuit breaker equipment was adequate, and also because feeder reactors would make it possible to maintain approximately 60% normal bus voltage even though lines were dead short circuited immediately outside the power house. Generator reactors on the other hand, would improve the conditions affecting the circuit breakers, but would not help the bus voltage at times of short circuit. These feeder reactors were finally purchased and their installation completed in 1918. The writer can say that a total interruption caused by outside line trouble has not occurred at the Duquesne Works since the completion of the installation of these reactors. There have been several total interruptions due to the failure of a feeder reactor iteslf. However, the original reactors have since been replaced with a more rugged design and reactor failures have not occurred since the installation of this improved equipment.

In 1926 and 1927, it became desirable to improve the electrical interconnection of the Carnegie Steel Co. Plants in the Monongahela Valley and also the plant of the National Tube Co. at McKeesport in order to more economically utilize available by-product fuel. After numberous studies of the economies of the situation, it was determined that the use of 44,000 volt twin circuit tower line of the same type of construction as used by the public utility systems on their more important lines offered the most economical solution of the problem. As the total length of the line is only 14 miles, the line reactance of the circuits between five different plants is comparatively small and it therefore became necessary to make a complete short circuit study of the entire system when interconnected. This study developed

*Elec. Supt., Carnegie Steel Co., Duquesne, Pa.

a number of apparent weaknesses in low voltage distribution systems which previously had not been appreciated. Among points which proved rather surprising was that the reactance of substations, transformers, and lines was greater than the interconnected aerial cable lines which had previously been used for connecting two of the plants. Even though the maximum capacity for power transmission over the high tension lines was five times greater than that of the cable interconnection.

It was also found that by properly adjusting the value of a bus and feeder reactance on all of the five stations which it was planned to interconnect that 6600 volt bus voltage at each of the individual plants could be maintained at approximately 60%, under short circuit conditions on any of the 6600 volt distribution systems. The short circuit calculating board also proved very valuable in determining the most effective system of relaying. The public utility relaying problems differ somewhat from that of a steel mill because of length(and therefore the reactance) of lines tying substations and power plants together are much greater than customarily found in the large steel plants. Therefore relays which depend on the drop due to reactance between substations to be effective cannot be used as successfully in steel mills as in the public utility systems. The use of simple over current or over current and differential relays combined, usually offers the best solution of the relay problem in the steel mill system.

There is one problem in connection with relaying which was overlooked in connection with the calculating board short circuit studies, viz., the fact that while it is possible by combining differential and over current relays to protect the plants against local or outside short circuit conditions so long as their normal generating capacity is operating, it has not so far been possible on our system to protect plants against local short circuit conditions when only a small part of their usual generating capacity is in service. To be more specific, the problem may be described as follows:

Assuming a plant having a normal load of 15,000 KW but on account of lack of available by-product fuel only operating 5,000 KW in generating capacity. The balance is being secured from the interconnecting line. A short circuit on the plant local distribution system will result in such a great inrush of current from the interconnecting line from the four other plants that it will trip the substation oil switches, thus disconnecting the plant from the outside sources of power. Adequate protection for trouble in the 44 KV system necessitates a short time setting on all substation relays. Therefore longer timing of 44 KV relays cannot be used to prevent a substation outage and the local steel plant is left with generating equipment in service heavily overloaded and part of the load must be dropped without warning to prevent more serious service difficulties. Perhaps some of our public utility engineers have had similar problems to solve and can make a suggestion which will help to correct this difficulty.

There is another problem which I would like to present to the relay specialists here this evening, and that is the matter of whether concentrated or distributed feeder reactance is more desirable on single ring feeder circuits. If the feeder reactance is concentrated at each end of the ring at the power house any line disturbance usually results in such a drop of voltage throughout the entire length of the ring that synchronous apparatus falls out of step. Would it be better to divide the total reactance of the ring by installing smaller reactances at the power house and other reactances at strategetic points in the ring circuits? I would be interested to hear from any one who has had experience along this line.

Up to the present time it has been accepted as almost essential to use the same voltage on large motors in steel mills as is used for the generating equipment. The amount of power required in the steel industry is rapidly increasing, and the current required to transmit this power at 6600 volts is becoming of very large magnitude. It would seem as if the time was near at hand when some change in the existing distribution practice was necessary.

A solution would be to use generating equipment rated at 13,200 volt; distribute power at this voltage, stepping down by means of auto-transformers to 6600 volts in mill motors. The opinion has been expressed by some designing engineers that satisfactory 13,200 volt motor equipment can be constructed for mill use so long as such motors are of the synchronous type, having relatively few slots in the stator core, permitting the use of coils with adequate insulation. Such motors should be just as reliable at the present stage of the art of insulation (particularly if provided with clean air for cooling) at 6600 volt motors of 15 years ago. Reducing 13,200 volts to 6600 volt for utilization in motors would be therefore required only for induction type motors, where the stator slots are many and the possibilities of insulating for higher voltages more restricted. It is hoped someone will be courageous enough to construct a 13,200 volt mill distribution system using 13,200 volt generating equipment, synchronous motors connected directly to the 13,200 volt line, and where induction motors are required, 2 to 1 auto transformers to reduce the line voltage for their requirements. If any one has an opinion to express on a more economical means of solving the problem of power distribution in our larger steel mills, it would be pleasing to hear their reaction to this proposal.

A. G. Darling*: The necessity for consideration of stresses on oil circuit breakers and consequential disturbances to system operation, is shown in Mr. Hussey's very complete history of his plant. Taken in time, many inconveniences can be relieved or eliminated by a thorough study of plant conditions and prospects for future expansion. This type of investigation is occupying the time of many plant engineers today, with noticeable improvement in plant operation. Systematic reviews from time to time as actual conditions change and plans for the future become more definite will be found profitable from the standpoint of continuity of service, as well as financially.

As each plant has its own peculiar conditions to meet, there can be no general solution for all. How-

*General Electric Co., Schenectady, N. Y.

ever, there are only a few major arrangements which prove effective in limiting short-circuit currents and retaining continuity of service. Given in the order of their effectiveness, some of these are:

1. Single generating station bus, radial feeders, no reactors.
2. Generating station ring bus sectionalized with reactance between generators and;
   a. Loop feeders with reactors from one bus section to substations and back to another bus section, or;
      a-1. to the same bus section.
   b. Radial feeders with reactors obtaining duplicate service from separate bus sections by two feeders in parallel, separated by a reactor at the substation end, or;
      b-1. the same arrangement, except radial feeders with reactors taken from one bus section.
3. Generating station bus sectionalized but not connected in a ring.
   a. Feeders same as 2-a.
   b. Feeders same as 2-b.
4. Synchronizing bus with reactors between it and generator buses.
   a. Feeders same as 2-a.
   b. Feeders same as 2-b.

For limitation of short circuit currents in substations, there are also a few major arrangements:

For single circuit supply:

1. No reactors.
2. Reactor on incoming line.
3. No reactor in incoming line but local feeders divided into groups with reactors feeding each group. The groups may consist of several or only one local feeder.

For double circuit supply:

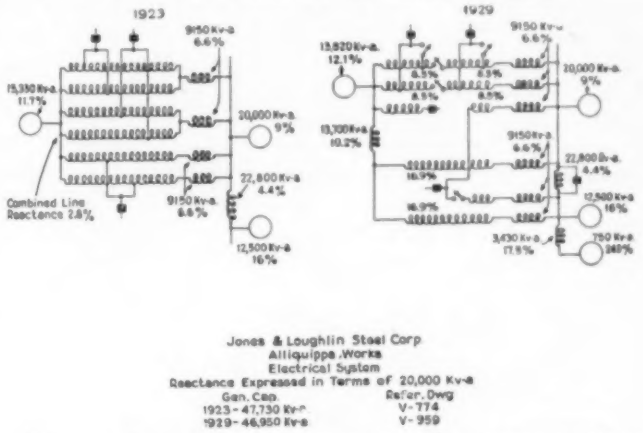
1. No reactors.
2. Bus sectionalized by reactor between incoming lines.
3. Reactors on each incoming line.
4. Combination of 2 and 3.
5. No reactors in incoming lines or bus but local feeders divided into groups, each fed by reactors; the groups may consist of several or one local feeder.

6, 7, etc.
Combinations of 5 with 2, 3 or 4.

Still another effective method which applies when the incoming feeder or feeders are heavy trunk lines is a reactor in the tap to the substation which in general will be of small capacity relative to the trunk feeders.

The plan adopted at the Aliquippa Works is in general a single generating bus sectionalized by reactors between generators. In the arrangement used in 1923, the North Power House (15,330 Kv-a.) is connected to the South Power House (20,000 Kv-a.) by lines and reactors, which, if combined together, would form a single reactance separating the 15,330 Kv-a. of generators from the 20,000 Kv-a. generator, resulting in a reactance of 4.6%.

The 1929 arrangement is essentially a similar one to 1923, but with materially different values of reactance between bus sections. To separate the North Power House (13,820 Kv-a.) from the South Power House, a 10.2% bus reactor was added and the trunk lines which previously connected these two sections together were opened. It will be noted that the North and South Power Houses are connected now by only two trunk lines from which all substation taps have been removed and that they have been connected, one to the 20,000 Kv-a. bus section and the other to the 12,500 Kv-a. bus section which serves to insure a connection between the power houses in case of a major bus section fault in the South Power House. At the same time this type of connection reduces the effective reactance between the two stations as both trunks are brought to one bus in the North Power House. Local conditions appear to have entered into this situation as they often do in other plants.



Jones & Loughlin Steel Corp
Aliquippa Works
Electrical System
Reactance Expressed in Terms of 20,000 Kv-a

Gen. Ceo	Refer. Dwg
1923 - 47,730 Kv-a	V-774
1929 - 46,950 Kv-a	V-959

The major change occurs in the means of reducing faults in the substations. In 1923 duplicate feed from separate trunk feeders was provided, while today radial single feed is used with an alternative feed not intended for continual parallel operation. There appears to be an opportunity here when conditions warrant, to use some of the means previously suggested to limit the faults in the substations and still obtain duplicate simultaneous service.

Mr. Hussey has presented comparative values of short circuit currents for the two stages of development, which indicate that material improvements as between the 1923 plan and Scheme A proposed. The following figures indicate the differences between the 1923 and 1929 results, leaving out of consideration the effect of synchronous apparatus in the substations, as it is felt mostly in the substation to which it is connected but has in this case only a minor effect on the system as a whole. The values are given in sustained symmetrical Kv-a.

	1923	1929	Red. in %
15,330 or 13,820 Kv-a.	Sect. 360 000 Kv-a.	238,000 Kv-a.	33
20,000 Kv-a.	Sect. 446,000 Kv-a.	374 000 Kv-a.	16
12,500 Kv-a.	Sect. 322,000 Kv-a.	326 000 Kv-a.	--
750 Kv-a.	Sect. ------	92,000 Kv-a.	--
Substation fed from 20,000 Kv-a. Bus.	220,000 Kv-a.	98,000 Kv-a.	55

The author presented a table showing the effects of short circuit on the voltage at various points on the proposed system. The value of this information is in regard to disturbance to rotating apparatus on other circuits than those immediately involved in the fault. Whether or not alternating current motors will remain in step during a disturbance and afterward recover their load is a function of many factors, including the design of the motor, the load

it is carrying, the duration and extent of the voltage disturbance and, with synchronous motors, the excitation of the field. To take all these into account would be a life work and the expectancy would be quite problematical. However, with the field excitation of the synchronous motors at approximately normal, the drop in voltage becomes one of the major considerations entering the problem. Knowing the short-circuit currents contributed and the reactance of the circuit involved, it is possible to predict the approximate voltage at points about the system which will occur at the time of fault. By an analysis of simple conditions in test cases, the figure of 60% has been taken as indicative of the motor remaining in synchronism when transient values of reactance are used. This value has proved to be sufficient in plants which were arranged to give it and more plants are being laid out with this consideration in mind. As more data becomes available, the figure of 60% may be modified.

Some importance must be placed upon the consideration of service continuity to motors remote from the fault to put this idea into practice as it upsets the economical balance which can be applied to establish the correct size of oil circuit breakers and reactors.

An analysis of failures by causes reveals some interesting data.

	1924	1925	1926	1927	1928	Total
Cable	2	1	-	-	-	3
Cable Terminals	4	-	2	-	-	6
Motor Windings	2	1	1	-	-	4
Lightning	-	2	2	2	-	6
Line Insulation	-	1	-	-	-	1
Interference	-	2	1	2	1	6
Faulty Operation	-	-	1	1	-	2
Miscellaneous	3	-	3	1	1	8
Total	11	7	10	6	2	36

The reduction in cable troubles indicates that sufficient cable capacity has been provided. Cable terminals and motor winding difficulties may be attributed to insufficient insulation for the voltages which existed or to voltages in excess of normal expectations. It is significant that these two causes gave no trouble in 1927-28, whereas they contributed ten failures in 1924-25-26. It is likely, as Mr. Hussey says, that the cable terminals were under insulated, and it is also probable that voltage surges have been kept down in number as well as in extent.

From the data shown, there is good reason to congratulate the men in charge of the engineering and operation of the plant upon the marked improvement in the design and results.

G. P. Wilson*: I am sure that all of us have enjoyed listening to Mr. Hussey's paper describing the construction and design of the power system which he has in operation at the Aliquippa Works of his company. While Mr. Hussey has not mentioned continuity of service, I feel, however, that this important idea runs through the entire length of his paper. I believe that he has given us a concrete example of the importance of continuity of electric service in a steel plant. Many of you men, no doubt, have run into problems similar to those discussed and described by Mr. Hussey. Due to these difficulties most of you are, no doubt, fully aware of the importance of having always available electric power in your plant. In the modern steel plant continuity of service is no longer an insurance but I feel an absolute necessity. Comparatively few plants can afford to have power interruptions occur very frequently. The loss of production and the high maintenance resulting from these outages is a serious item in the production of steel.

The modern manufacturing methods which require a mass production make it very important that we do everything within reason to provide for continuity of service. I wish to emphasize in commenting on Mr. Hussey's paper, a few of the things which he has done to his own system to guard against power outages. I personally feel that it is just as foolish to operate a steel mill without spare or reserve source of power as it is to operate an automobile without a spare tire. None of us, I am sure, would be so careless or indifferent to our comforts and expenses as to even attempt to travel a very great distance without a spare tire. The first thing we do when we buy a car is to buy a spare tire if one does not come with the purchase price of the car. It is true that we may not need the spare for some time, but it is also true that we might have a flat tire before we get the car home, and it is this uncertainty that makes us pay considerable attention to the spare. This same idea is applicable to furnishing spare unit or reserve capacity to your power system. If it is possible to do so, several sources of power is very desirable. This is well illustrated in Mr. Hussey's paper. He has two separate power-houses. I realize of course, that in a great many plants this condition may not be permissable. However, I feel that under present conditions that more use might be made of the public utility or central station system in the steel plants. This power to be used either as a standby service or as a source of power to be utilized as the demand in your plant requires. If operated in parallel with your own power system it will, I believe, provide an excellent reserve for emergency purposes.

Reserve Capacity and separate sources of power are only two of the items however which may be utilized for providing against power outages. To provide ample assurance that reserve capacity will be utilized to the best advantage, it is essential that we have a well planned and well constructed distribution system. To illustrate our meaning we will again use the automobile as an example. I am quite sure that all of us who own and drive an automobile will agree that under present day conditions that it is mighty convenient if not essential that we have several roads leading from one point to some other point. These parallel roads permit diverting traffic when a road is being repaired and naturally eliminates interference and delay. The same principle holds true in power distribution. It is essential that we have parallel lines if we wish to give the best guarantee of continuity of service. One will find, in many of the steel plants this idea of parallel circuits as illustrated in Mr. Hussey's paper. The power distribution system illustrated in the Aliquippa Plant is a radial type system with parallel lines. The physical layout of the Aliquippa Works makes this type of system practically necessary. A

*General Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

second scheme of distribution which is becoming quite generally used in steel mills is the ring bus system. I appreciate that this type of system could not be used to the best advantage at the Aliquippa Works due to the arrangement of the mills and the physical dimension of the property. However, where the mills are distributed in such manner that the ring bus system can be utilized, I believe that continuity of service can be maintained much better with this type of system than with the radial type. This is due primarily to the fact that a great many of the circuits feeding individual mills do not always have parallel circuits and a second reason that usually parallel circuits are carried on the same pole line so that if trouble develops on one circuit it is quite apt to be transmitted to the other and both of them will be put out of service. The ring type construction with which you are familiar is a continuous circuit with the various mills tapped off at points in the ring. The ring should be sectionalized so that trouble developing on any one point will be completely isolated and power fed into the remainder of the mills over two general feed lines.

Another very important consideration and one which should not be overlooked in providing the proper guarantee of service in your plant is protection. Protection not only against external but internal causes. This subject of protection may be divided into two general classes. One class which deals with external causes on transmission line failure such as lightning discharges and insulation flashover. This protection is important and should be provided. The matter of abnormal voltages on power systems due to lightning or arcing grounds and the effect of these transient voltages on the equipment installed in ones plant should be given a great deal of attention. Mr. Hussey has pointed out in his paper that he increased the voltage rating of all his line insulators in order to reduce outages and lessen trouble due to surges caused by lightning and the flashing over of insulators. This has been the trouble in all the steel plants. I believe that this custom of over insulating the line will however eventually lead to worse trouble. It must be obvious to all that if the transmission line is insulated abnormally, equipment connected to the line should also be over insulated or protected in some other way from these abnormal surges. A surge which might ordinarily spill over an insulator on normally insulated line if over insulated will probably reach the equipment itself thereby causing failure. Most of you, no doubt, appreciate that it would be rather expensive for the manufacturer to build apparatus which would take these abnormal voltage conditions. The stresses due to abnormal operation such as arcing grounds and those caused by lightning are often many times higher than what the standard insulation is designed for.

To eliminate this condition on an isolated system particular attention should be paid to the lightning arrester. This arrester should be shunted by a suitable safety gap. The gap setting should not be in excess of the flashover values recommended by the manufacturer. A second method which appeals to the writer as being more satisfactory is to ground the neutral of your system. The grounding of the neutral will permit a lower setting of the lightning arresters and thereby relieve the system of the excess voltage at a much lower value than would be possible with the isolated system.

In connection with this idea of over insulation of the line, it might be pointed out that the accumulation of dirt and dust on the insulators does not lower the flashover voltage of them as rapidly as one is probably lead to believe. We have made tests on insulators and found that the flash value of a cleaned insulator and a dirty insulator differs only about 15 or 20 per cent. We made a test on a 44,000 volt line insulator quite recently. These insulators were rated at 66 Kv, and supporting a 44,000 volt line on a pole very near a blast furnace. We had the steel company to provide us with insulators, one of which had not been cleaned for three or four months and one that was cleaned in accordance with their general practice of cleaning insulators. These insulators were taken off the pole at the same time and brought to our factory for test. The cleaned insulator had only dropped about 5 per cent below the original insulating value. The insulator which had not been cleaned for four months was only about 10 per cent below the cleaned insulator, making, therefore, a total of approximately 15 per cent. This test was taken as a dry flash over and also as a wet flash over. This test may not, however, be conclusive. It is my opinion that with the lower voltages the type of insulator is such that probably the ratio between the flash over of a dirty insulator and a clean insulator will be much greater than with the higher voltage type of insulator which is built up as a string of individual units.

The second class of protection which is important on a transmission system is to equip the system with relays connected so as to sectionalize the trouble and keep it to a minimum. This naturally involves a very complete study of your system so as to equip each circuit with the proper kind of relay. On a ring bus system proper relays can be furnished and so connected as to isolate any section. With radial system this is not always so easy to accomplish, but with a reasonable amount of study given to it considerable may be done in guarding against outages.

Mr. Hussey has very clearly pointed out to you the necessity of providing oil circuit breakers with ample interrupting capacity. I am sure that most of you appreciate the importance of having oil circuit breakers on your system which will handle successfully short circuit conditions. It is comparatively easy at the present time to make the proper application of oil breakers to any system. This should be borne in mind and ample precautions taken to guard against failures due to the application of wrong oil circuit breakers. I realize, of course, that quite frequently it is hard to foresee the growth of a plant and that sometimes we are unable to provide breakers which are adequate for future developments. We should, however, take into account a reasonable expansion of the system and select breakers accordingly. If the expansion of the plant is of such a value that the type of breaker is exceeded a comparatively small amount we can often relieve the situation by the installation of line reactors. Line reactors are coming more and more into general use in the steel plants. Operators are beginning to realize that heavy short circuits are injurious not only to the breakers, but also to the power system in general. The mechanical forces set up in your

whole system under heavy short circuit condition may be of such a magnitude as to weaken it mechanically. Reactors if properly applied will relieve this condition quite materially. Reactors will not only relieve the bad effects due to the heavy short circuit current, but also assist in maintaining voltages on your system permitting quite frequently synchronous apparatus to remain in operation under severe short circuit conditions. This, to my mind, is one of the most important advantages of reactors.

In closing I wish to compliment Mr. Hussey on the way he has put this problem before you. I feel that he has done it in such a way as to call forcibly to the minds of all of us the importance of continuity of service in our plants, and by giving some concrete examples of how he has improved operating conditions, he has given us some very good and beneficial information.

B. M. Jones*: The paper presented today by Mr. Hussey is very interesting, and should be doubly interesting to you electrical people of the steel plant, whose everlasting cry is "tonnage and more tonnage." From even a casual reading of Mr. Hussey's paper and only indifferent attention to the presentation thereof today, it is apparent to any one in the electrical game that material and beneficial results have been obtained from the replacement of inadequate breakers and associated protective devices with modern adequate breakers which will take care of the present conditions and allow for future expansion and growth, and the author should feel a great pride in the correction of a very unsatisfactory situation of long standing.

Part 2 of Mr. Hussey's paper on the description of power failures and troubles is, to my mind, the most logical basis from which to start on such a program, for you must know what troubles and difficulties have been experienced before you can expect to get authorization to correct any trouble.

The electric transmission system of a large steel plant, similar to Mr. Hussey's plant, is considerably difficult, in many respects, from the electric transmission system of an operating power company, such as the Duquesne Light Company. Our lines are scattered all over the county, and of course are much longer, but are not subjected to the physical hazard from adjacent structures, such as would be encountered in steel plants in the way of cranes and other equipment, nor are our lines subjected to as much dust and dirt (for the most part) as lines in a steel plant. Mr. Hussey uses a much larger insulation factor, and which appears to be entirely justified, than we do.

A very interesting portion of Mr. Hussey's paper was that portion referred to as "ungrounded systems" in the latter part of the paper. In the A. I. E. E. Proceedings of 1923 there is a report of the Protective Devices Committee of this Institute which goes into the subject of present day practice in grounding of transmission systems quite thoroughly, and is a very interesting report. I mention this because I personally feel that some of Mr. Hussey's previous troubles, and possible some in the future, but it is hoped that they will be very few, may have been due to the fact that he was operating his 6600 volt system ungrounded, with the result that all troubles that the circuit breakers were called upon to interrupt were short circuits, and, therefore, of a severer duty than would have been the case with a grounded system where a great majority of the troubles would have been single phase to ground faults.

On the Duquesne Light 66 kv. transmission system, which is a double circuit transmission system on steel towers, there were the following number of single phase to ground faults, single phase short circuits and three phase short circuits during the years 1925 to 1928 inclusive:

	Number of Line Faults			Number of Station Faults			Total Number of Faults		
	1-ph. Grounds	1-ph. Shorts	3-ph. Shorts	1-ph. Grounds	1-ph. Shorts	3-ph. Shorts	1-ph. Grounds	1-ph. Shorts	3-ph. Shorts
1925	34	0	4	9	0	1	43	0	5
1926	29	7	0	4	0	0	33	7	0
1927	20	4	0	8	0	0	28	4	0
1928	21	3	2	1	2	0	22	5	2
Total	104	14	6	22	2	1	126	16	7

Tabulation of Faults on Overhead Lines for 1928

	1-ph. Grounds			1-ph. Shorts			3-ph. Shorts			Total	
Kv.	No.	% of Total	Return to Service	No.	% of Total	Return to Service	No.	% of Total	Return to Service	No.	Ret. to Service %
66	21	80.8	16	3	11.52	1	2	7.68	-	26	14 53.8
22	86	56.6	67	34	22.35	11	32	21.05	4	152	82 53.9
11	1	33.3	--	1	33.3	--	1	33.3	-	3	-- ---
Total	108	59.66	80	38	21.0	12	35	19.34	4	181	96 53.0

From this tabulation it will be seen that there is a total of 126 single phase to ground faults, with 16 single phase to single phase faults, and seven three phase short circuits. This 66 kv. transmission system is grounded through 63 ohms at two points, and the resultant ground faults cannot exceed 1300 amperes, while the short circuits that can be encountered at different points on the system vary from 5000 to 12000 and greater. This tabulation shows that about 85% of all 66 kv. faults were single phase to ground, with a resulting maximum fault current of 1300 amperes. This, of course, is much easier upon the breakers than the 5,000 to 10,000 amperes of short circuit, and we have experienced no difficulty with these breakers on the troubles encountered, but with an ungrounded system, our experience might have been very different.

On other voltages, 11 and 22 kv., the tabulation above shows the number of single phase to ground,

*Equipment & Protection Engineer, Duquesne Light Co., Pittsburgh, Pa.

single phase shorts and three-phase shorts.

From the above tabulation, it will be noted that approximately 60% of the total number of faults are single phase to ground faults, with the resulting less severe duty on the circuit breakers, for the 11 and 22 kv. systems are both grounded through resistors, through 15 ohms and 3.75 ohms respectively.

This above tabulation also shows that 53% of all line troubles were returned to service immediately. This means that after the breakers opened, they were reclosed at the end of two minutes and remained closed, thus indicating that the line was satisfactory. This also means that the fault was of such a low magnitude that 53% of the line troubles did not burn the line down or sufficiently damage the insulator to prevent re-establishment of service, and we feel that this is in a large proportion due to the resistor grounded system, and the installation of adequate ground relays, for our records for years past have shown that the percentage of lines returned to service has increased by a large amount, since the installation of ground relays and the resistors.

It might appear that undue emphasis is being given to the matter of a resistor grounded system, but I am personally convinced that this is the best method of operating a transmission system that encounters many troubles, and in the Protective Devices Committee paper in the A. I. E. E. in 1923, as previously referred to, the trend is very clearly toward resistor grounded systems, and the reasons therefore are given.

It is apparent that Mr. Hussey went after this problem of providing adequate breakers in a very thorough manner and made a complete short circuit study which is very sound engineering, and from which basis he seems to have convinced his management that the expenditure was necessary.

The matter of short circuit studies has become very important in the last few years, and our Company bought a short circuit calculating table about three years ago, and now actually calculates the short circuits that will flow under all possible conditions before any changes are made to our transmission system, and frequently find that the duties imposed on certain breakers are so severe that we must resort to other means of transmission connections to limit this duty, such as reactors or different bus connections.

I understand that Mr. Egan of the Lackawanna Plant of the Bethlehem Steel Company made a study similar to Mr. Hussey's, of their plant a few years back, and set up a program to provide adequate breakers and switching equipment.

It costs money, and a lot of money, to replace inadequate circuit breakers and switching equipment in a system of any size, and Mr. Hussey undoubtedly realized this when he set about to correct the unsatisfactory conditions in his plant, but I think that we will all agree with him that inadequate circuit breakers should be replaced with adequate breakers just as rapidly as possible. Our Company spent quite a large sum of money in 1927 and 1928 replacing circuit breakers in the 11 and 22 kv. class, due to the growth of our system, and due to the improvement in oil circuit breakers. The writer mentioned this before your Society at the Pittsburgh meeting in December, 1927.

I notice with interest that Mr. Hussey gave due and proper consideration to the thermal capacity of the breakers as well as the interrupting capacity. This is one of the determining factors in applying circuit breakers properly where there are enormous currents involved for the first few cycles of the short circuit, and which high current has been reduced materially by the time the breaker opens due to the decrement of the generators. This is particularly true in breakers close to the power house, and quite frequently necessitates the installation of a larger breaker than would be required for the interrupting duty alone. However, the larger breaker is justified for you will certainly get the high current for the first few cycles as often as you will get the severe interrupting duty upon the breakers.

It appears that the matter of space was a serious item in Mr. Hussey's program, and that additional ground space was not to be had under any conditions in certain cases, and that rather ingenuous methods were used to overcome this handicap.

The use of reactors and bus splitting schemes apparently helped Mr. Hussey out of some of his difficulties, and I might say that similar schemes have been used by power companies for exactly the same purpose, and have certainly reduced the duty on breakers with resulting saving in money in purchase price of breakers.

In the last part of Mr. Hussey's paper I notice that he mentioned certain plans they have or may have for the future, and in such plans I would make the suggestion, if I may, that the grounded system, solid or resistor, be given serious consideration to further lessen the duties on the breakers and to reduce the ever present possibility of shaking off the motors driving the main rolls due to the severe voltage dips and surges on the system.

I would like to say that it is well worth while for you steel plant electrical people in any short circuit study or circuit breaker installations to plan for the future, the distant future. As mentioned before, they have a two acre field vacant now, but do not know what mill may be installed there, nor what additional generating capacity will be required to carry this mill; therefore, they must guess at it and buy and install breakers now elsewhere in the mill that will be adequate at some future date.

Duquesne Light Company with whom I am now connected, have a county and a half of territory, and do not know where the next large load will be required, and, therefore, must make plans to provide adequate circuit breakers for anything that may develop. Recently we installed a new Highland Substation near Washington boulevard in Pittsburgh, Pa., fed at 66,000 volts from our Colfax Power Station. The installation of this station necessitated very careful study of the short circuits in this district, for this Highland Substation fed adjacent substations at 22,000 volts, and raised the short circuit current appreciable in this and surrounding districts. It was necessary to resort to a three bus scheme at East End Substation to avoid replacing certain breakers recently (a year or two ago) installed in this station. This would have meant a considerable amount of money, and the sectionalizing scheme allowed us to retain the present breakers which are

amply adequate with sectionalizing methods. I mention this merely to show that you must plan for the future in applying breakers for any additional capacity will certainly burden the breakers to a greater and greater extent. Most of the large utility companies strive to have plans for their future growth abreast of the growth, and try to install equipment that will be adequate for the future growth as it comes.

Our company has a calculating board that we bought from the Westinghouse Company for several thousand dollars, and we feel that this money is very well spent. Previous to the purchase of this board, the calculations were made by the slide rule long-hand method, and were laborious and expensive and could not cover all conditions as satisfactorily as the calculating board can. The load factor on our board for the last year or two has been one man's full time.

I cannot agree with Mr. Wilson's remark on the relaying of a radial system compared to a loop system, wherein he stated that the radial systems were much more difficult to relay. We have been using the loop transmission system and associated relaying schemes for some five, six or seven years, and have been struggling manfully to improve our relaying, and it has been quite a task. Our relaying performance has gradually improved from 85 per cent in 1925; 91 per cent in 1926; 92½ per cent in 1927; 96.7 per cent in 1928, and 98½ per cent in January, 1929, and 100 per cent in February, 1929 I can assure you all that it required eternal vigilance, both night and day, to improve our relaying performance, and we only wish that we had had a radial system to relay, for we feel that we would have arrived at 100 per cent several years sooner.

In connection with Mr. Cummins' remark, at the early part of this meeting, relative to a certain relay problem he had, we encountered a relay problem something similar to this a year or two ago, and feel that we have a satisfactory solution, and I would be pleased to discuss this with Mr. Cummins at any time.

J. S. Murray*: Our Association may well feel proud of having men of the ability of Mr. Hussey among the membership who find time to furnish such useful data such as he has presented tonight. The circuit breaker question has not received very much attention in steel mill systems until a few years ago. This was natural, as steel mill power systems were comparatively small. Power systems in steel mills today are very large, very important, and require supervision and maintenance of the same caliber at least as the central station system of the public utilities. The oil circuit breaker and relay system is a very important part of the steel mill power system, and will, in my opinion, become more important in the very near future, as systems of private generating plants enlarge their capacity or extend their connection to the public utility systems or a combination of both. It is also very encouraging to note the splendid co-operation that steel mill engineers are getting from the circuit breaker manufacturers in helping to meet the exacting requirements of steel mill service.

*Chief Elec. Engr., Follansbee Bros. Co., Toronto, Ohio.

I have a few questions that I would like to ask Mr. Hussey:

1. What method do you use in testing relays on oil circuit breakers periodically? How do you record these tests and follow them up?
2. Relay sequence. Time between settings.
3. Do you use choke coils with all lightning arrester installations? I would like to have your opinion and the opinions of others on the value of choke coils on short transmission lines in steel mills on 2300 and 6600 V. circuits.
4. What spacing of conductors and what is the span between towers on the 600,000 C. M. Cable you mention in your paper?
5. Have you found bad cable encased in conduit with pot heads satisfactory in feeders entering substation and control rooms? If so, what voltage ratings do you use on 6600 Volt service?
6. Are you using any varnish combination cable with weatherproof tread but no lead in conduit steel or otherwise with ordinary weatherproof conduits for feeder entrances? If so, are they satisfactory?
7. Are you using any underground cable systems in your plant?

R. M. Hussey: In answer to Mr. Murray's questions, I would answer as follows:

1. We have no well defined procedure in testing relays on our oil circuit breakers periodically. We are now set up to check the setting of relays periodically, making casual inspection of same and recording them in a card index file.
2. There is no real good answer to this question as to relay sequence and time between settings. We have endeavored to bring about relay settings whereby branch feeder circuits trip first in case of trouble, or in case of heavy short circuits, feeder relays lock-in their respective switches and short circuit currents rupturing through heavy duty breakers.
3. It is common practice with us to use choke coils with all lightning arrester installations. We believe that choke coils at dead ends of all lightning arrester installations will tend to clear the line of transient voltages through the lightning arresters.
4. In all of our new work we have used a spacing of 42 inches between conductors placed in the shape of equilateral triangles. In some work where we revamped existing equipment, we have some 36-inch spacing, and in some part of the transmission line on which we have not yet done revamping work, there are some 28-inch spacings. Our poles and towers are spaced about 150 feet apart, except in the case of two 100-foot towers where we spaced about 300 feet.
5. We do use lead covered cable encased in conduit with cable terminals at either end for our feeder branches to substa-

tions and control rooms, and have experienced comparatively little trouble. In some cases I believe we have 15,000 volt cable installed.

6. We have used very little cable not lead covered in conduit. The small amount of such cable with the conduit has given no trouble to date.
7. We do not call our system an underground cable system. We use underground cable only when necessary to tap into some overhead line and go underground to a substation.

---

*Cleaning Air by the Adhesive Impingement Method**

By J. H. MILLIKEN†

The subject of our meeting this afternoon is "Air Conditioning." Air conditioning has two major divisions of interest, the first of which has to do with delivery of air to the human occupants of building spaces of the proper temperature, humidity, cleanliness, and in the right amounts to insure their comfort and health. The second division has to do with supplying air to industrial processes having proper characteristics to assure the carrying on of these processes effectively and economically.

In steel mills we are particularly concerned with the use of air for cooling mill drive motors, turbo generators and auxiliary electrical units. Inasmuch as the sole function of this air supply is cooling, the only concern would be temperature and quantity, were it not for the fact that dirt is in this air no matter where taken about the plant.

Dirt very readily accumulates in electrical machines due to the abrupt changes of velocity and direction of the air streams in these machines, which acting somewhat in the manner of an air cleaner, throw the greasy dirt against the internal surfaces, causing it to lodge in the slots, windings, ducts, etc.

Due to the fact that any air supply carries large amounts of dust, considerable thought has been given to the possibility of cooling mill motors and other apparatus in motor rooms by a constant recirculation of the same air using coolers for eliminating heat much in the manner of the recirculation of air or gas recently used in turbo generators.

Using a recirculation system it is possible to keep the dust out of the machine and have clean windings only when the recirculated air is handled in a complete metal duct system with air tight joints. This is practical on a generating unit wherein the expense of this arrangement is justified by keeping the volume of combustion supporting gases as small as possible but is not usually practical with a number of mill motors or other small units.

It has been found by experience to be impossible to make a building sufficiently tight to prevent the infiltration of dirt wherein a portion of it is under suction, even though you disregard entirely the fact that the windows, doors and hatches will be opened, from time to time, in the natural operation of the plant. Tests have shown that a very small leak, due to its low resistance and high velocity, will infiltrate such a large amount of dirt as to materially affect the overall efficiency of the cleaning system. Also if D.C. machines are being used, brush dust will be constantly accumulating.

From the economic standpoint, this arrangement is impractical because no advantage is taken of the low yearly average outside temperature, permitting reduction in the amount of air to be forced through the machines and a consequent saving in H.P. involved in handling the required amount of air at less than summer maximum.

If the building be closed up as tight as possible and all of the air recirculated, the total amount of dirt handled by the fans will be materially decreased but eventually nearly all of it will lodge in the machine windings due to constant recirculation and the actual results obtained so far as the prevention of dirt is concerned will not be appreciably better than they would be if outside air were used without any means of cleaning.

Therefore, it is necessary that an efficient air cleaner be installed in series with the coolers if the machines are to be kept clean.

Basically the removal of solid matter from air or other gases is divided into four methods:

First, the trapping of dirt by centrifugal or baffling arrangements depending upon the laws of inertia and mass. The most common example being the arrester or cyclone.

Second, precipitation by means of electrical polarization which is known as the Cottrell system.

Third, the mechanical wedgement or entanglement of solid matter in screens or nap of cloth as exemplified by ordinary screens, bag filters, etc.

Fourth, the adhesive impingement method, which is the subject of this paper.

A device based on one of these methods may utilize one or more of the others to a certain extent. The first two methods are used for handling dirt in heavy concentrations and are widely used in industrial applications but are not concerned with the fine cleaning necessary in ventilation or cooling mill motors.

The earliest attempts to clean air used for venti-

---

*Presented before Combustion Engineering Division of the A. I. & S. E. E., at Duquesne, Pa., Jan. 24, 1929.

†Vice President, Reed Air Filter Co., Louisville, Ky.

lation or industrial processes were usually along the line of screens made of metal or cloth. Everyone was more or less familiar with the use of much materials for filtering liquids, bolting, etc., and these methods were obviously utilized by reason of their familiarity.

It is ,of course, possible to get a very high cleaning efficiency by passing air through a layer or series of layers of very dense cloth or paper but certain inherent disadvantages are at once apparent. The action of this sort of a filter largely depends upon the lodgment of dirt particles in the interstices of the weave of the material through which the air passes and as one of these small interstices becomes filled with dirt there is that much less opening for the air to pass through, consequently the resistance of the device increases rapidly in proportion to the amount of dirt that is being collected, so some means must be found for removing this dirt as fast as it collects or by frequent renewal of the filtering material if the impedance to the air flow is to be kept within any reasonable bounds. This sort of air cleaner is in use to a certain extent today and where the inconvenience of the resistance is not objectionable can be made to do extremely efficient cleaning.

About the year 1900 the first air washers of a commercial type were introduced and proved to have a great many advantages as a consequence of which it became standard practice to install air washers on all good ventilation projects and on industrial projects where the high humidity was not a detrimental factor. It was claimed for the air washers that they were very efficent in the removal of dirt from the air, that they cooled the air, and that they also added very desirable humidity.

In the early days of promulgation of the air filter, objection was raised by nearly every engineer and architect specifying air washers that with filters installed instead of air washers a very vital factor in the ventilation system, namely humidification, had been eliminated. We did not find this objection so strong on the part of the operating men and although there may be no apparent reason for it, nearly all of the large ventilation jobs go in today without any means being provided for this matter of humidification, and on many jobs where air filters were installed to reinforce the air washers from the air cleaning standpoint, the air washers were discontinued from operation and apparently everybody is as well or better satisfied that formerly, from the standpoint of humidity. This humidity factor is, of course, in cooling work not necessary or even desirable.

The cooling claimed for an air washer is of great interest to the member of this Society because the majority of applications of air in your work is for the purpose of carrying away heat and obviously the cooler the air the more rapid the transfer of heat. The cooling by the air washer depends entirely upon the conditions under which it is operated. If cold water, say 65° Farenheit or less be used, then the air will be cooled in its contact with the spray and the flooded eliminator plates. This is the only basis on which the cooling of an air washer can be constantly and effectively obtained and be used as a factor in computing the engineering characteristics of the air job under consideration.

This is very common practice in modern theaters, restaurants, hotels and some offices where constant air temperature is maintained. In this connection, refrigerating plants are nearly always used as there is little possibility of obtaining cold water from other sources, at the points where these applications might occur. In large centers, architects and engineers now have standardized on the use of air filters in all fresh air supply systems where the above conditions of cooling cannot be afforded.

When the air being blown through the washer has low moisture content, then cooling will be obtained by the evaporation of the water in the washer but this will depend upon the difference in the wet and dry bulb temperatures at the particular time.

Theoretically this cooling is 70% of the difference between the wet and dry bulb temperature, thus the difference in the wet and dry bulb temperature might be 15 degree Farenheit and then 10 degrees cooling will be obtained on the delivered air. This, however, is of little practical benefit in your engineering calculations as the very day on which your equipment might be overloaded to the point where this difference in cooling would be of benefit might be the very day in which the incoming air was near saturation humidity and the cooling would not be obtained.

If there is a condition where this air is constantly being taken over hot furnaces, ovens, mills or some such thing and the temperature of the air being delivered to the unit to be ventilated has been increased over the outside temperature and the humidity content has been decreased, then the cooling effect of the air washer would be obtained and the water equipment would be desirable apparatus.

Perhaps in the early days of the air washer when the amount of fuel consumed in any given square mile was only a fraction of what it is today, the air washer was more efficient in cleaning than it is today because a larger percentage of the dirt was easily wet by water and could be removed by the washer. Thorough investigation in recent years under our present conditions has shown that the efficiency of washers in removing the dirt consisting mostly of soot and related matter is not sufficiently high for the purpose.

If larger amounts of greasy soot are allowed to pass into the windings this will block up the smaller air passages eliminating cooling entirely where that occurs and cut down the rate of heat transfer in the others so that air filters must be used even if a washer is on the job. In this connection, I would like to point out that the first device embodying to a certain extent the principal of adhesive surface impingement with which we are concerned in this paper is the air washer. It was usually thought that the spray on an air washer was the means for knocking down the dirt, but some careful checks made on air washers disproves that. In certain types 90% or more of the total cleaning accomplished by the washer was done on the eliminator plates. Many of the dust particles removed would be wet to a certain extent by the spray and carried by the air stream to the eliminators where they would adhere to the wet plates and thus be washed down to the sediment pan.

In fact, some air washers have been produced and sold using no sprays at all, having only flooded

eliminators of various sorts and apparently are about as efficient as the spray type.

In the design of air cleaning devices there are certain fundamentals of considerable importance. The most important of these is the efficiency in the removal of dirt. If the air filter would be no more effective in this respect than other devices from which at times you might obtain desired humidity or perhaps some cooling, there would be no reasonable excuse for their application because an air filter has no other function than removing the solid matter from the air.

The second important factor is resistance to the air stream by the surfaces picking up the dirt. Eliminator surfaces using water could probably be so arranged as to get a fairly good efficiency but in doing this the resistance would be increased to a point far beyond commercial practicality. The most important and radical step in the design of air filters was the use of an adhesive liquid or medium having much higher surface tension than water and consequently greater facility for holding the particles of dust that have been impinged against the coated surface. Thus, immediately was accomplished the important fact that an equivalent surface was capable of picking more dirt out of the air stream with the same velocity and consequently no increase in resistance. In commercial practice this adhesive medium is usually mineral base oil refined to certain specifications. It has been found after a great deal of empirical investigation that surfaces can be so disposed in the air stream using an oil binding medium as to obtain very high cleaning efficiency and keep the resistance as low or lower than air washers and well within a commercially practical range.

The first air filters of the impingement type used in this country were the cell or unit familiar to everyone and in this filter cell a large amount of adhesive surface is obtained by packing metal of various shapes, usually small in section, into a frame approximately 20″ x 20″ square and 3″ to 4″ thick. In this type of filter the smaller the section of metal filament used, the more surface that can be obtained in a given cubical content. These small filaments thoroughly sub divide the air giving intimate contact resulting in high cleaning efficiency. Due to their small size they do not produce abrupt changes in direction or flow or areas of negative pressure, consequently the total resistance is low.

This type of filter is intended to be dipped in the special oil, allowed to drain for 24 hours or more until the major portion of it is drained out and is then placed in the air stream where it accumulates dirt for a period of a few days to a few weeks depending upon the amount of dirt in the air to be handled, at which time a fresh one is put in its place and the dirty one taken out and washed by hot water or steam and then dipped in the oil again. The handling of these units is done by what we call the rotation process, that is, a certain amount of these filter units are cleaned at regular intervals consequently the total installation has some freshly cleaned, some dirtier, and so on, and by a constant schedule on this rotation, the resistance of the total filter bank is kept at a practically constant figure.

In the design of the unit filter it is necessary to provide that when it has been dipped in the oil it will retain sufficient of this oil to moisten all the dirt that may be collected in it over this period because if the oil would all be absorbed quickly by the dirt there would then be some dry surface presented and the adhesive impingement principal would be lost to a large extent, permitting the dirt to go on through the filter. If the filter is so designed that it will not hold sufficient oil to moisten all the dirt passing into it, it will then become dry and permit the dirt to go through and if the cleaning of the filters is neglected, the air ducts will rapidly become very dirty. If it is designed as previously outlined and the cleaning of the filter is neglected, then the resistance will steadily rise until the point where no air can pass through the filter so it is essential that cleaning of unit filters be put on a definite schedule and maintained.

There are thousands of installations of this type of filter and they are extremely satisfactory wherever the rotation cleaning is faithfully carried out.

The amount of dirt to be handled in the steel mills is usually so great that it necessitates frequent cleaning of these units which becomes a burdensome task, consequently a filter that would clean air as well as the unit filter and at the same time take care of itself in some way so as to relieve the necessity of this hand washing has been desired by large users of air filters. A great deal of thought has been given to this and a number of types of automatic or self cleaning air filters have been offered on the market. The most obvious line of experiment was to construct a filter similar to the unit type of filter in nature and then build some means of automatically washing the dirt out of and re-charging it with the oil.

It was found that the dirt collected on the filter surfaces in a film of oil would readily be floated off by oil if it had free access to the dirt with a slight relative motion. Thus, the cleaning and charging of the surface can be done with the same liquid medium.

A number of attempts have shown it to be extremely difficult to produce a filter maintaining this density of mass of filter media as used in the unit filter and clean it by running oil through it or by simple immersion in oil. One of the inherent troubles is oil entrainment, which is important and has been the subject of much discussion in air filter work.

As we have pointed out the unit filter is dipped in the oil and then allowed to drain free of this oil before being put back in the air stream and the instructions of all manufacturers are particular about this point.

If it were dipped in the oil and then put right back into the air stream it is more than likely that so many of the interstices in the filter itself would be filled with drops of oil that a static resistance would be built up behind it sufficient to force through some of these interstices producing a high velocity jet which would carry the oil out of the filter into the air stream. This oil would be carried along until the velocity had dropped sufficiently for the action of gravity to work on the particles of oil and allow them to drop in the casing. The specification for oil used for this work demands that volatile matter be eliminated; if proper oil is used there is practically no evaporation or condensation

in the operation of the filters. If ordinary grades of oil are used, this condensation may be considerable.

Consequently, in designing automatic filters it is essential that it be so done that no points of high velocity are possible where there may be an accumulation of oil which would be carried out of the filter into the air stream.

Our research department found it almost impossible to overcome these difficulties in the dense media belt type of filter and developed an automatic impingement filter wherein we again went to larger surfaces and higher impinging velocities. This surface was formed into vertical struts or tubes round on the side against the air stream and streamlined behind the air stream and arranged in rows across the air stream.

The air is speeded up as it passes between the struts in one row and at this higher speed impinges on the struts in the next row where it again drops in velocity, speeds up and impinges on the following row. All told this occurs nine times in passing through the filter. The streamlining of these tubes reduces the overall resistance so materially that sufficient impingement surface can be used in this manner to get very effective dirt removal.

If these tubes were dry and the dirt were dry the only cleaning that would be accomplished would be the dropping out of dirt by reason of gravity as is done in other trapping arrangements, consequently the most vital element in this filter is maintaining the adhesive film of oil on the surface of the tubes where the dirt hits it. This portion of the tube is coated with bakelite and wood flour which due to its nature holds a thicker film of oil on that part of the surface.

Automatic arrangements are provided for taking the oil from a reservoir in the bottom of the filter to the top of the filter and allowing it to flow down over these tubes in a uniform manner which takes off the dirt and leaves a fresh film of oil. This is done each time the fan is shut down or every eight hours.

The advantage of this type of filter is that there is no place for the accumulation of dirt except on these straight surfaces and it is therefore easily self cleaned. There is a considerable clearance between the struts in a row and consequently the oil or dirt cannot bridge over from one to another and the resistance will always be constant.

It is absolutely necessary that the air flow be off this filter while it is being flushed with the oil because if the velocity be on it while the oil is running down it will carry the oil around the streamline tubes and have it run down the back of the tubes where the dirt does not accumulate, instead of the front surface where the dirt is. Under the proper velocities this oil will not be carried off the filter while it is flushing but as is pointed out, it will also be ineffectual in cleaning the filter so this "air off" the filter is imperative.

Due to this limitation, this filter which is handling several million cubic feet per minute of air in ventilation work, cannot be applied to mill motors, generators, sub-stations and any other work where continuous operation is necessary.

Our experimental department being unable to make a satisfactory filter using a continuous belt made up of sections similar to our unit filter wherein fine metal filaments were packed in a promiscuous manner between retaining surfaces of expanded metal, decided that this filter medium would have to be in a form that would be self supporting. As we have previously pointed out, irregular outline and rough surfaces are of considerable help in the filter medium whereas in going to a mechanical form a smooth surface and regular outline would have to be used.

In experimenting with woven wire screen we found that if this screen be coated with a bakelite and wood flour mixture that was so effective on our streamline filter, due to the tooth so to speak that this material would put on the wire it would be very effective in holding a thick film of oil, and consequently picking up the dirt and this led to the development of our Multi-Panel Continuous Filter which is thoroughly self cleaning, automatic and more efficient in dirt removal than any filter we have been able to make.

This filter is made up in the form of an intermittently revolving vertical screen. It is made in standard sections of approximately 30″ and 4′ in width and in height up to 13′. Each section has a driven shaft at the top carrying two chain sprockets with a fixed shaft at the bottom carrying two loose sprockets and a tension adjustment for tightening the vertical chains running over the sprockets. Each link of these two chains carries an eye which supports a horizontal steel rod. From this rod is suspended a corrugated double woven screen panel approximately 8″ wide which has been coated with the bakelite. This panel has a spot welded loop around the horizontal rod and also has a small stiffening rod at the other edge. These panels lap on each other while in the air stream to form the necessary thickness to get the maximum cleaning efficiency.

This continuous belt of panels revolves through an oil reservoir at the bottom which oil washes the dirt off the panels and leaves a film of oil on them as they again come up into the air stream. In operation this belt of panels is revolved ¾″ every twelve minutes. This is accomplished by a telechron type of electric interrupter which every twelve minutes closes a solenoid switch energizing the driving mechanism which in the case of steel mill work is a solenoid operating a ratchet on the end of the drive shaft.

We use this drive rather than a constant speed gear reduction because we have found that the intermittent travel at a higher speed insures the cleaning of the panels in the oil reservoir. It has been previously pointed out that the removal of dirt from the filter surfaces depends upon relative motion in the oil bath.

When these panels reach the oil at the bottom they separate one from the other and due to the fact that this screen is comparatively large in mesh and regular in outline the movement through the oil very readily washes the dirt off the panels that has been accumulated. As they move further they come up out of the oil separately, which makes quick draining of surplus oil possible, and after this draining has been complete they begin to lap and move into the air stream where the filter is in effect re-assembled for the air cleaning operation.

Thus it will be seen that due to two very simple and radical changes in air filter methods, we have eliminated all the inherent troubles of continuously moving filters. The bakelite treatment gives us cleaning efficiency of better than 99% and the panel separation insures thorough cleaning, proper draining and consequently no possibility of oil entrainment or clogging of the filter. The dirt accumulates in the bottom of the oil reservoir and we have provided a very simple false bottom to each tank section which can be removed from the reservoir when it becomes filled with sludge, taken out, and the dirt dumped out of it. On very large installations it will undoubtedly be an economy to provide a central oil handling plant piped to the various filter sections wherein the oil can be cleaned by sedimentation or other means.

As to the method of determining the efficiency of air filters, there has been a great deal of discussion as to the various highly technical methods for doing this, but we have found that the operating man usually sizes up the situation by stating that the apparatus or equipment that he is protecting by the filter, is clean or dirty, rather than giving an abstract discussion of thousandths of a grain per cubic foot, color charts or that sort of thing, so we recommend a visual comparative test. To simplify this we have made comparators in the form of a recessed opening or cup in a celluloid plate with a hole through it so arranged to insure the air coming in contact with this surface when passing through it. This cup is coated with a light layer of white vaseline and rigidly suspended in the air stream both before and after the device to be tested, and the relative cleanliness of the air will be easily observed after a few hours or days, depending upon the amount of dirt in the air being handled.

Tests made in a well known steel plant showed the efficiency to be considerably better than 99%. These plates had been placed in the air stream before and after the filter for a continuous period of 142 hours.

---

*Spring End Trucks for Cranes**

By JOHN MUNTZ†

Resilient mounting of wheels on vehicles is so generally accepted as a matter of course that it would scarcely occur to anyone to design a vehicle of any kind to travel on roads without the resilient mounting of its wheels, even for modern smooth and hard roads. Probably the first horse-drawn street cars were tried without spring mounting of the wheels, but if so, it must have been early recognized that resiliency in the mounting of wheels was a necessity, and an early primitive type of such mounting consisted merely of a thick rubber block between axle box and car frame. This was soon discarded in favor of a still more resilient mounting and the more the speed of travel of a vehicle was increased, the greater attention was bestowed on the resiliency of such mounting.

Overhead traveling cranes are vehicles with very small wheels and very great mass in comparison with other vehicles, two factors which should tend to emphasize the desirability of resilient mounting, yet due probably to the fact that few persons travel on cranes, desirability of resilient mounting of track wheels on cranes has been very much overlooked.

Railroad equipment while rolling on tracks supported by wood ties on stone or gravel beds, forming a splendid resilient base in itself, is further cushioned by use of leaf or helical springs. Overhead crane runways are cushioned in no such manner, and the runways themselves may be in far less perfect state of repair than the railroad tracks. Therefore, up to the present, the overhead crane has had to meet conditions of runway considerably worse than the railroad and it has not been fortified with the cushion obtained through springs with which every railroad car and locomotive is adequately equipped. While the speeds of railway equipment are far greater than those of traveling cranes, the railroads as a rule do not carry the delicate electrical equipment used on present-day cranes. When they do, as in the case of electric railways, not only are the cars well cushioned by springs, but the frequency of use of such equipment is very much less than the continuous operation of the several movements of an overhead crane.

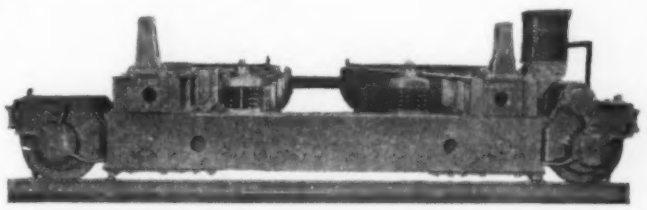


Fig. I. Spring End Truck

Largely at the suggestion of Mr. E. L. Upp, the Shaw Spring Type End Truck was developed a few years ago, and the results obtained from the use of same have proven so encouraging that it seems a safe prediction that when this construction has been further demonstrated and generally understood, there will be speedy development of the idea of providing even greater resiliency. This in turn probably will permit higher traveling speeds than now employed.

The advantage of mounting the bridge of a crane on springs was quickly recognized in mills where this construction has been employed. Electrical Superintendents look for less maintenance cost of the electrical equipment due to the elimination of shock and jar to the crane itself; bolts remain tight, and, whereas it may seem a trivial matter to state that the operator is much less fatigued, it neverthe-

*Presented before Chicago District Section of the A. I. & S. E. E., April, 1929.

†Chief Engr., Maning, Maxwell & Moore, Shaw Crane Works, Muskegon, Mich.

less is the case that the operators have definitely stated their preference for running the spring truck cranes; the smoothness and freedom from jar is immediately apparent, particularly so where the runway is in bad shape and there are gaps in the rail joints.

The beneficial effect of this construction on the runway and the building itself is even greater. The runways on which spring truck cranes operate are subject to far less shock, rail clips remain tight and the general condition of the runway is greatly improved which again means considerably less maintenance cost.

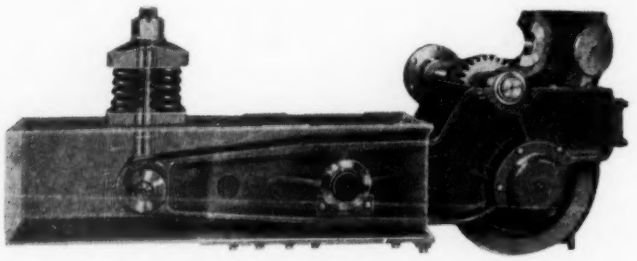


Fig. II. Phantom View of Spring End Truck

The construction of the spring end truck is exceedingly simple and yet unique in several instances. The bridge girders are joined by a hollow box section steel member and are rigidly attached thereto using the usual notched construction and gusset plates. Directly under the line of the trolley rails there is a fulcrum pin on which is suspended a smaller member, or equalizer, the wheel end of which incorporates the axle bearing, either roller or M.C.B., the cross shaft end bearing and the bumper block. The other end of this equalizer is forked and drilled for an eye bolt. The eye bolt extends up through a hole in the box section and is suspended on a nest of four car springs. Adjustment of the spring compression is obtained by a large castelated nut on the eye bolt. The eye bolt end of the equalizer extends into the box section and is well supported for side thrust by bronze thrust washers that bear directly against large bearing pads on both sides. Provision has been made for lubricating all moving parts.

Discussion--Surveys of Lighting and Voltage in the Steel Industry

A. J. Standing*: I think we enjoyed the paper presented by Mr. Hibben this morning. Papers vary somewhat. Sometimes the author of the paper is rather shy of material and the value of the meeting must be made up by extemporaneous remarks from the listeners. This morning, however, this is not the case. This was so extremely replete with information that I think all of us operating men have gained a great deal from Mr. Hibben's paper.

I have a number of notes here for discussion, but as you realize, we have a paper to follow, and while this is the last electrical session of the convention, we don't want to play too much on your good will and overrun our meeting too long, so the discussion must necessarily be very much curtailed.

I don't think lighting conditions can be as bad as Mr. Hibben's survey shows in plants where the electrical department is under the control of members of this Association. If those conditions to obtain there, then I certainly am ashamed of the Association.

I would like to ask H. L. Johnson of the Duquesne Light Company to give us his end of this lighting situation.

H. L. Johnston†: I am here, Mr. Chairman, primarily to hear something from the experience of the operating men present. Being with the utility, our lighting work covers a very broad cross section of the field. We are particularly interested locally in the problems of the steel industry.

Our findings in the commercial as well as the industrial field are very much along the same lines as outlined by the previous speaker. Very often the lighting system develops a section at a time without definite plans for a complete system, frequently resulting in inadequate wiring for the complete plan. This inadequate condition obtains quite generally throughout the industrial and commercial lighting field.

A case came to my attention recently which requires an improved lighting system. In order that a suitable system may be developed, a complete electric service must be provided from the panel board to the lighting equipment.

In looking over the situation and reviewing the different industries, the point that strikes me most forcibly, is that of the automobile industry—one of the most recent, and still a very strong and healthy one, is in foremost providing for the use of adequate light. This use of light is based on increased production and a lessening of the accident hazard.

A. J. Thompson*: Supplementing what Mr. Hibben has said in his very interesting and instructive talk I want to emphasize, in just a word, the importance of frequency of cleaning, in the matter of lamp maintenance.

There are three or four points of advantage growing out of frequency of cleaning—the more frequent it is done, of course, the more light will be thrown down into the working area; the work will be done easier if done before the dirt has become dried or baked on. The easier it is the less time it will take, and the less time it takes the less it will cost

*Elec. Supt., Bethlehem Steel Co., Bethlehem, Pa.
†Duquesne Light Co., Pittsburgh, Pa.

*Pres., Thompson Electric Company, Cleveland, Ohio.

—all of which tends toward maximum service from the reflector at the minimum cost.

The greatest problem in reflector cleaning is accessibility—the means of accessibility should be adapted to the conditions where the work is to be done. It would be interesting to see how far one of those step-ladder trucks would be able to penetrate the average steel plant, foundry floor, blast furnace plant, forge shop, etc.

The logical means of accessibility in most places, especially in steel mill work, is afforded by a lamp lowering switch, which enables the work to be done on the ground in a position of safety, where the man can work in comfort and with efficiency.

It seems a pity for people to pay what they have to pay for as good a piece of apparatus as a modern reflector is, and then put it up in such a way that they make a joke of it, because somebody forgot or overlooked making adequate provisions for accessibility so that the reflector could be kept in proper working condition.

George Pfeffer*: There is one thing that comes to my mind. I think it would be a decided improvement if the reflector manufacturer could devise some coating that would better withstand the action of the gas and the dust than the present coating.

In the majority of cases, where the reflector is cleaned, the person who cleans it resorts to an abrasive such as sand. The result is that the reflecting surface is soon destroyed. There are many cleaning compounds on the market which the reflector manufacturers could recommend to their own advantage and also to the advantage of the person using the reflector. We have used several such compounds with very good results—in several cases, reflectors which at the first glance looked as though they were beyond cleaning, were cleaned with very good results, and without damaging the reflecting surface.

There are many places that I have gone to visit that bear out Mr. Hibben's remarks as to the proper maintenance of lights. The last thing that seems to receive attention is the cleaning of reflectors, with the result that the lighting, which originally was very good, at the end of three or four months is very poor. Nothing pays bigger dividends than good lighting. It receives less attention than anything in the plant.

*Florence Pipe Foundry & Machine Co., Florence, N. J.

A. J. Standing: There is a certain tie between the two papers presented this morning, as far as the complaint of low voltage is concerned. Oftentimes a light in the circuit may benefit by the voltage necessary to operate magnetic controllers. Perhaps we pay more attention to adequate operating voltage on controllers than on lighting, but the lighting rides along and get the benefit anyhow.

I think, however, that all of us in our plants today are paying a great deal more attention to what used to be called more or less unimportant details, because we realize those details are costing us money, and everyone today has got the cost feature pretty thoroughly implanted in his mind. If he doesn't have, it will pretty soon be put there.

So the proposition of adequate lighting in safety and production, efficiency and economy, and the necessary wiring voltage to produce that, reflect directly on the cost of our operation as does any other feature of our more or less miscellaneous equipment in the steel plant.

S. G. Hibben: In regard to the last remarks on non-tarnishing reflectors, I think you are all familiar with the fact that the equipment manufacturers are striving to get these harder-surface and more durable reflector units. Without question, the prismatic glass is durable, although the question of accidental breakage is always a factor. The biggest step forward I think in recent months has been the application of chromium plating to metal. The chromium-plated metal surface, when properly prepared, will withstand ordinary abrasives. It is about the hardest surface we know. It is untarnishable, but it has to be prepared on a hard backing. Ordinary chronium on soft copper may break through. So with a little further study of chromium-plating, I think we will solve the problem of the cleanable surface, and have unbreakable reflectors.

Electric Heating and Welding Conference

AUSPICES

PENNSYLVANIA STATE COLLEGE

AND

ASSOCIATION IRON AND STEEL ELECTRICAL ENGINEERS

NOVEMBER, 1929—PITTSBURGH, PA.

CO-OPERATORS,

THE INDUSTRIAL PLANTS, WESTERN PENNSYLVANIA
THE CENTRAL STATIONS, WESTERN PENNSYLVANIA
THE ELECTRIC HEATING FURNACE MANUFACTURERS OF AMERICA
THE WELDING EQUIPMENT MANUFACTURERS OF AMERICA
THE ELECTRICAL HEATING UNIT MANUFACTURERS OF AMERICA
THE IRON AND STEEL INDUSTRY

(Continued from Page V)

W. J. Davis, Chief Elect., Scullin Steel Co., St. Louis, Mo.
F. A. Tremallen, Foreman Pwr. House Lines, Bethlehem Steel Co., Johnstown, Pa.
D. W. McFadyen, Chief Elect., Universal Portland Cement Co., Universal, Pa.
William Anderson, Chief Elect., Sellers Mfg. Co., Chicago, Ill.
W. P. Stark, Chief Elec. Engr., Apollo Steel Co., Apollo, Pa.
James Riles, Elec. Supt., A. M. Byers Co., Pittsburgh, Pa.
I. J. McAnlis, Chief Elec., Standard Steel Car Co., New Castle, Pa.
J. R. Lytle, Chief Elect., Vulcan Mould & Iron Co., Latrobe, Pa.
James H. Reiners, Elec. Engr., Pgh. Screw & Bolt Co., N. S., Pittsburgh, Pa.
George Pfeffer, Chief Elect., Florence Pipe Foundry & Machine Co., Florence, N. J.
J. C. Ritchey, Elec. Engr., Pressed Steel Car Co., McKees Rocks, Pa.
J. D. Scully, Elec. Supt., National Tube Co., McKeesport, Pa.
R. F. Waldo, Dist. Mgr., Ideal Commutator Dresser Co., Pittsburgh, Pa.
H. McFarland, Sales Mgr., Martindale Electric Co., Cleveland, O.

AIR CONDITIONING

Chairman, R. E. Lewis, Elec. Supt., Youngstown Sheet & Tube Co., Youngstown, O.
J. H. Milliken, V. P., Reed Air Filter Co., Chicago, Ill.
J. L. Harphan, Pres., National Air Filter Co., Louisville, Ky.
T. E. Hughes, Genl. Foreman, Carnegie Steel Co., Duquesne, Pa.
W. B. Reese, Elec. Engr., Great Lakes Steel Co., Ecourse, Mich.
R. M. Hussey, Elec. Supt., Jones & Laughlin Steel Corp., Aliquippa, Pa.
W. S. Hall, Elec. Engr., Illinois Steel Co., Chicago, Ill.

TRANSPORTATION COMMITTEE

Chairman, Frank Mohr, Warren Plant, Republic Iron & Steel Co., Warren, Ohio.

SHOP PRACTICES COMMITTEE

Chairman, J. J. Booth, Asst. Elec. Supt., National Tube Company, Gary, Ind.

COMBUSTION ENGINEERING DIVISION

EXECUTIVE COMMITTEE

Engineering Section Director, F. E. Leahy, Comb. Engr., Youngstown Sheet & Tube Co., Youngstown, O.

Chairman, Martin J. Conway, Lukens Steel Co., Coatesville, Pa.

W. N. Flanagan, Special Engr., Carnegie Steel Co., Pittsburgh, Pa.

L. C. Edgar, Chief Engr., Carnegie Steel Co., Braddock, Pa.
W. J. Harper, Fuel Engr., Donner Steel Co., Buffalo, N. Y.
H. C. Seibert, Comb. Engr., Bethlehem Steel Co., Bethlehem, Pa.
J. W. Jones, Steam Engr., Wheeling Steel Corp., Portsmouth, Ohio.

Gas Utilization Section

Chairman, W. N. Flanagan, Special Engr., Carnegie Steel Co., Pittsburgh, Pa.
A. G. Witting, Chief Engr., Illinois Steel Co., Gary, Ill.
F. G. Cutler, Chief Bureau of Steam Engr., Tenn. Coal Iron & R. R. Co., Ensley, Ala.
J. G. West, Gen. Supt., N. S Works, Jones & Laughlin Steel Corp., Pittsburgh. Pa.
A. J. Boynton, Engr., H. A. Brassert & Co., Chicago, Ill.
W. H. Cosgrove, Pres., Gas Combustion Co., Pittsburgh, Pa.
W. E. Bisler, Engr., Combustion Engr. Corp., New York, N. Y.
J. C. Hayes, Engr., Freyn Engineering Co., Chicago, Ill.
Karl L. Landgrebe, Gen. Supt., Tenn. Coal Iron & R. R. Co., Ensley, Ala.
J. W. Jones, Steam Engr., Wheeling Steel Corp., Portsmouth, Ohio.
Wilfred Sykes, Asst. Gen. Supt., Inland Steel Co., Indiana Harbor, Ind.
W. J. McGurty, Bartlett Hayward Co., Baltimore, Md.
C. W. Hedberg, Research Corp., Bound Brook, N. J.

Gas Producer Section

Chairman, A. G. Witting, Chief Eng., Illinois Steel Co., Gary, Ind.
W. P. Chandler, Blaw Knox Co., Blawnox, Pa.
E. A. Hawk, Steam Engr. Dept., Tenn. Coal Iron & R R .Co.., Ensley, Ala.
G. R. McDermott, Vice Pres., Chapman Stein Furnace Co., Mt. Vernon, O.
A. L. Foell, Chief Engr., Donner Steel Co., Buffalo, N. Y.
Walter deFries, Ch. Engr., Wm. B. Pollock Co., Youngstown, O.

Steam Generation and Utilization

Chairman, L. C. Edgar, Chief Engr., Carnegie Steel Co., Braddock, Pa.

E. W. Trexler, Supt. of Mech. Dept., Bethlehem Steel Co., Johnstown, Pa.

J. B. Crane, Engr., Combustion Engr. Corp., New York, N. Y.

James Rath, Power Dept., National Tube Co., McKeesport, Pa.

J. D. Donovan, Elec. & Mech. Supt., Central Alloy Steel Corp., Massillon, Ohio.

E. Kieft, Engr. of Tests, Illinois Steel Co., Gary, Ind.

C. H. Verwohlt, Works Engr., Wheeling Steel Corp., Wheeling, W. Va.

J. H. Van Brunt, Vice Pres., Combustion Engr. Corp., New York, N. Y.

Liquid Fuel Section

Chairman, W. J. Harper, Comb. Engr., Donner Steel Co., Buffalo, N. Y.

R. S. Coulter, Steam Engr., Bethlehem Steel Co., Sparrows Point, Md.

Prof. W. Trinks, Carnegie Institute of Technology, Pittsburgh, Pa.

Fred Clements, Engr., Park Gate Works, Rotherham, England.

H. C. Seibert, Combustion Engr., Bethlehem Steel Co., Bethlehem, Pa.

J. H. McElhinney, Gen. Supt., Lukens Steel Co., Coatesville, Pa.

Furnace Section

Chairman, H. C. Seibert, Comb. Engr., Bethlehem Steel Corp., Bethlehem, Pa.
S. Kneass, Chief Engr., A. M. Byers Co., Pittsburgh, Pa.
A. W. Steed, Supt. Maint., American Rolling Mill Co., Middletown, O.
Karl H. Marsh, Chief Engr. British Empire Steel Co., Sydney, N. S., Canada.
G. T. Hollett, Steam Engr., Illinois Steel Co., South Chicago, Ill.
J. F. Spellacy, Gen. Supt., Wheeling Steel Corp., Steubenville, O.
L. Ellman, Vice Pres., M. H. Detrick Co., Pittsburgh, Pa.
Joseph Kennedy, Julian Kennedy Co., Pittsburgh, Pa.
A. L. Culbertson, Dist. Mgr., Rust Engineering Co., Pittsburgh, Pa.
W. R. Culbertson, Sales Engr., Chapman Stein Co., Mt. Vernon, O.
E. H. Younglove, Johns Manville, Inc., Chicago, Ill.
A. G. Witting, Chief Engr., Illinois Steel Co., Gary, Ind.
C. H. Hunt, Chief Engr., Weirton Steel Co., Weirton, W. Va.
S. Naismith, Refractory Engr., Illinois Steel Co., So. Chicago, Ill.

Instrument and Control

Chairman, J. W. Jones, Wheeling Steel Corp., Portsmouth, Ohio.

J. G. Allen, Chief Engr., Carnegie Steel Co., New Castle, Pa.

W. P. Chandler, Special Engr., Blaw Knox Co., Blawnox, Pa.

Carl Fischer, Supt. Light, Heat & Pwr., Mesta Machine Co., W. Homestead, Pa.

G. R. McDermott, Vice Pres., Chapman Stein Co., Mt. Vernon, O.

R. M. Walker, Dist. Mgr., Bristol Co., Pittsburgh, Pa.

G. D. Conlee, Chief Engr., Republic Flow Meters Co., Chicago, Ill.

H. R. Maxon, Pres., Maxon Premier Burner Co., Muncie, Ind.

J. M. Hopwood, Pres., Hagan Corporation, Pittsburgh, Pa.

C. H. Smoot, Pres., Smoot Engineering Co., New York, N. Y.

SAFETY ENGINEERING DIVISION

EXECUTIVE COMMITTEE

Engineering Section Director, Walter Greenwood, Youngstown, Ohio.
Chairman, C. E. Sankey, Ch. Safety Director, National Tube Co., Pittsburgh, Pa.
C. L. Baker, Managements Repr., Bethlehem Steel Co., Lackawanna, N. Y.
R. G. Adair, Supv. of Safety, American Rolling Mills Co., Middletown, Ohio.
Earl Blank, Dir. of Safety, Jones & Laughlin Steel Corp., Pittsburgh, Pa.
A. C. Germain, Safety Dir., Minnesota Steel Co., Duluth, Minn.
H. G. Hensel, Safety Engr., Youngstown Sheet & Tube Co., Indiana Harbor.
F. H. Rowe, Safety Engr., Wheeling Steel Corp., Portsmouth, Ohio.
P. F. Haberstick, Safety Engr., Wheeling Steel Corp., Benwood, W. Va.
J. A. Voss, Safety Dir., Central Alloy Steel Corp., Massillon, O.
J. A. Oartel, Safety Dir., Carnegie Steel Co., Pittsburgh, Pa.
J. A. Northwood, Safety Dir., Bethlehem Steel Co., Sparrows Point, Md.
P. G. Fenlon, Safety Dir., Carnegie Steel Co., Duquesne, Pa.
J. F. Hunter, Safety Engr., Carnegie Steel Co., Pittsburgh, Pa.
F. H. Kittredge, Elec. Supt., Illinois Steel Co., Joliet, Ill.
Stanley Grand Girard, Elec. Engr., Sharon Steel Hoop Co., Sharon, Pa.
G. A. Lamberton, Gen. Foreman, National Tube Co., Lorain, Ohio.

DISTRICT SECTION CHAIRMAN AND SECRETARIES

CLEVELAND DISTRICT SECTION

Chairman: A. L. Reichert
Secretary: J. E. Wood

CHICAGO DISTRICT SECTION

Chairman: Fred Acker
Secretary: A. J. Whitcomb

PHILADELPHIA DISTRICT SECTION

Chairman: Norman C. Bye
Secretary: Linn O. Morrow

PITTSBURGH DISTRICT SECTION

Chairman: Wray Dudley
Secretary: John F. Kelly

BIRMINGHAM DISTRICT SECTION

Chairman: E. C. Winfield
Secretary: J. B. Looney
Vice Chairman: Birger Thele

EXECUTIVE COMMITTEE

E. P. Winters
J. E. Sayer

PAPERS COMMITTEE

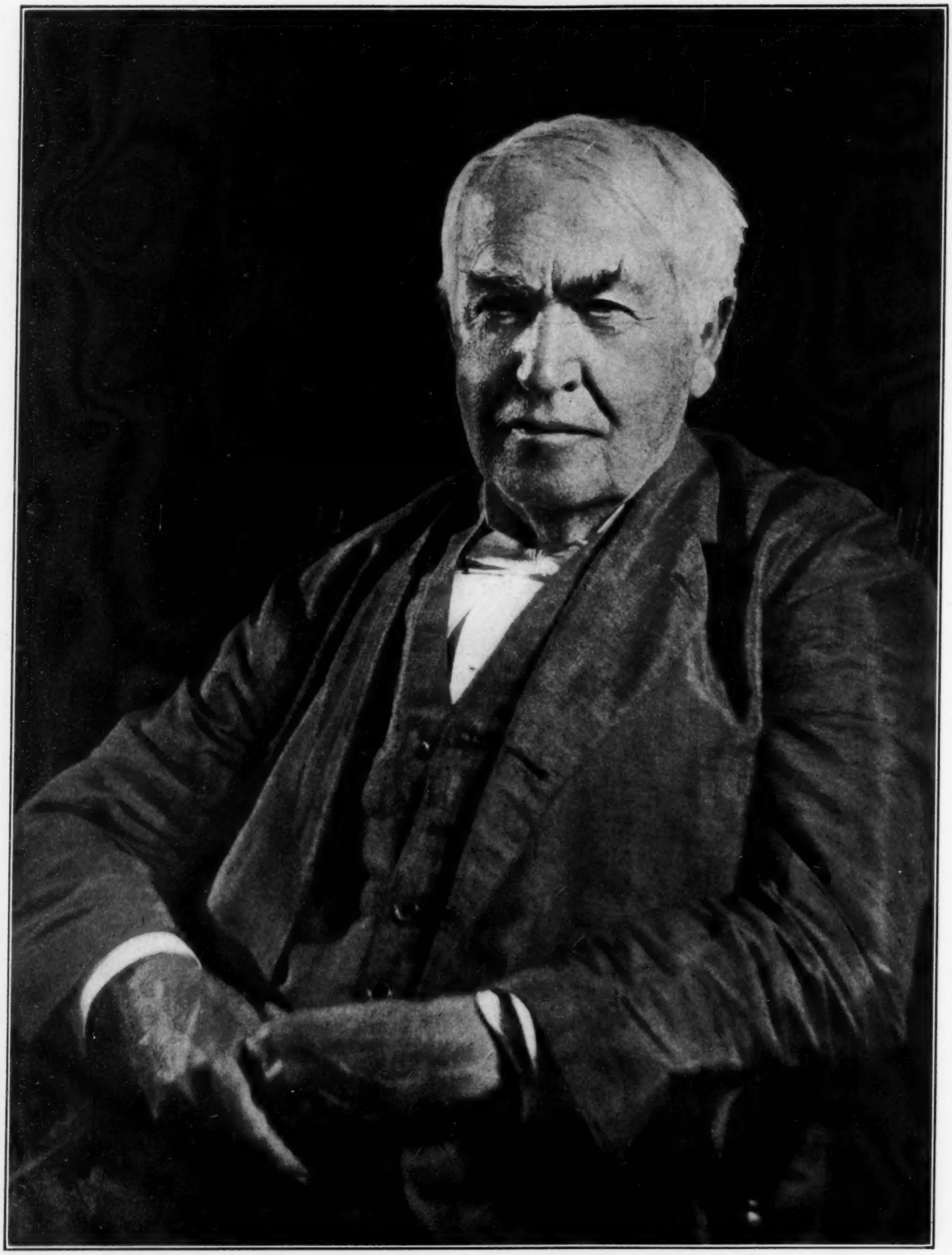
A. E. Hawk
W. J. Donahue
E. S. Lammers
C. L. Redd

MEMBERSHIP COMMITTEE

W. H. Gilbert
J. E. Harrell
A. C. Spring

ENTERTAINMENT COMMITTEE

A. F. Elliott
K. S. Lord
A. L. Lemon



Mr. Thomas A. Edison, Scientist, Philosopher, Inventor and Engineer. During the month of October, over 300 cities in the United States will celebrate the fiftieth anniversary of the invention of the Incandescent Lamp with parades, pageants and public gatherings.

Items of Interest

Of interest to Shop Superintendents and material handling executives is the recent appointment of Mr. George R. Harrison as Cleveland Representative for the Reading Chain and Block Corporation, of Reading, Pa., with offices at 362 Rockefeller Building, Cleveland, Ohio.

Announcement has just been made of the appointment of Blake C. Hooper as Sales Manager of the Baker Industrial Truck Division of the Baker-Raulang Company, Cleveland, Ohio.

In addition to his new duties as Sales Manager of the Baker Industrial Truck Division, Mr. Hoover will continue in active charge of the company's railroad department.

Mystic Iron Works has retained Freyn Engineering Company as consulting engineers in connection with work contemplated at its plant near Boston, Mass.

The Roller-Smith Company, 233 Broadway, New York City, announces a new issue of its Bulletin No. 810, covering its Types TW, FW and STW thermo-couple ammeters and milli-ammeters for direct current and alternating current of all frequencies, including radio frequencies.

The Type TW (3½") and FW (4") cover a range of 100 M.A. to 20 amperes and the Type STW (7½") from 10 to 100 amperes.

These instruments incorporate a new and improved form of thermo-couple, which is distinguished by very high overload capacity and sustained accuracy over a wide range of temperature.

A copy of the new Bulletin No. 810 will be forwarded upon request.

The Asano Bussan Company has retained Freyn Engineering Company in connection with the design of a complete blast furnace plant to be located in Japan.

The Hyatt Roller Bearing Company, of Newark, N. J., are now manufacturing single row radial bearings to satisfy a demand for a roller bearing interchangeable with standard S. A. E. single row ball bearings, but having greater load capacity. This new Hyatt line, made up of solid rollers, is not intended to replace the standard Hyatt Roller Bearings, but is offered as a supplement to it, for positions in which space limitations exist and loads beyond the capacity of ball bearings must be sustained.

The United States Electrical Manufacturing Company, with headquarters in Los Angeles, California, have prepared a very interesting booklet entitled "The Story of U. S. Motors," describing their various types of motors and applications, newest developments in design and various methods of manufacture. The book is written in semi-technical fashion and is well illustrated with photographs and technical delineations. Copy of this booklet may be procured by any one interested.

The Edwin L. Wiegand Company, makers of Chromolax heating units have moved their factory and offices to 7500 Thomas Boulevard, Pittsburgh, Penna. The new factory will give increased facilities for manufacturing and engineering on various heating units.

The George D. Whitcomb Company, of Rochelle, Illinois, have recently prepared a booklet entitled, "Locomotives with Internal Combustion Engine Drive." This booklet outlines the advantages effected by using locomotives powered with internal combustion engines. Copies will be sent to all interested parties on request.

The National Safety Council will hold their Eighteenth Annual Safety Congress in Chicago, September 30th to October 4th. Meetings in the Stevens, Blackstone and Congress Hotels. Exhibit will be held in the Stevens Exhibit Hall.

A new catalogue on Centrifugal Blowers and Compressors for Gas Plants, Blast Furnaces and General Industrial Service, is being distributed by the De Laval Steam Turbine Company, of Trenton, N. J. The catalogue describes applications, design and construction, manufacturing methods and materials and compression of gases. The catalogue is freely illustrated with photographs and charts. Copy of the Catalogue F may be obtained by application to the above office.

The Delta-Star Electric Company, Chicago, Illinois, have ready for distribution bulletin No. 70, describing and listing their new drop forged "Uniclamp" pipe fittings.

This is a radically new type of fitting, comprising five parts from which innumerable combinations can be assembled in the field.

Copy of this bulletin will be mailed upon request.

The Farrell-Birmingham Company, of Buffalo, New York, has recently completed a metal forming mill of an entirely different type to those which have been in use during the last twenty years. The design of this new mill conforms closely to the design of continuous mills for rolling hot bar and strip.

Each stand is an individual unit and has an individual drive. Formerly it was the practice to drive a series of rolls through a train of spur gears which resulted in noise, vibration and surge or tramp and which was clumsy and inflexible.

Each individual drive uses bevel gears encased in cast iron and receives power from a single back shaft driven by one motor.

The individual stand houses the spindle bearings, the connecting gears and the mechanism for adjusting the roll centers. It has greater strength and heavier weight than the previous designs. It provides a solid and stable installation which improves the quality and finish of the product.

With the individual stand it is possible to add or subtract from the mill from time to time as

different shapes of metal are formed. On heavy production work a duplicate set of stands can be made ready so that at the finish of one production job the changeover can be immediately effected.

Both the stand and the gear drive unit are fitted throughout with anti-friction bearings and are lubricated automatically. This is done to ensure high efficiency, reliability and smooth silent transmission of power.

The adjustment for the top roll spindle is worthy of particular attention. Both top and bottom spindles are held rigidly to the roll housing during the rolling operation and there is therefore no backlash and wear.

The top roll spindle is carried in anti-friction bearings in a single saddle and is placed against the cap by heavy springs and held in place by guide plates.

The wedge, which is free to move in and out, is inserted between the top roll spindle saddle and the housing cap. This movement is controlled by the horizontal screw thread with a hex head on the outside.

To elevate or depress the top roll spindle it is only necessary to turn the hex head of the screw to the right or left. By the introduction of two cap bolts which pass through the cap of the roll stand and the wedge, and are threaded into the top roll spindle saddle itself, this saddle and the wedge can be clamped tight against the cap when the mill is at work.

All materials entering into the construction of this metal forming mill have been selected with great care. The steels are heat-treated and of alloy analysis. Semi-steel is used instead of cast iron.

Development of a new metal known as "Konel," which is credited with being much stronger than other metals at high temperatures and which can be used extensively in the moving parts of internal combustion engines and other extremely hot places, has been announced by officials of the Westinghouse Electric and Manufacturing Company. The announcement followed the granting of foreign patent rights.

Originally developed by the Westinghouse Research Laboratories as a substitute for platinum in the manufacture of filaments for radio tubes, the new metal was discovered to be harder to forge than steel, and to be very tough at high temperatures, when most metals lose their strength. Engineers predict many uses for Konel.

The new metal was created by Dr. E. F. Lowry, a graduate of Ohio State University. As a substitute of platinum, Westinghouse officials are authority for the statement that Konel already is saving approximately $250,000 monthly in the manufacture of radio tubes.

Platinum costs approximately $180 per ounce, while the new substance costs only a few dollars a pound. Life of Konel filaments is approximately ten times longer than other filaments. Tubes with filaments made of the new metal are operated 175 degrees colder than tubes with platinum filaments but with the same emission, thereby giving better reception results, research engineers say.

Last year it was a notable feat when electrical engineers, after months of patient working, watching and waiting in the Allegheny Mountains obtained the first oscillographic picture of a natural lightning surge on a high voltage transmission line. This year the story has been much different,—obtaining such lightning records has been reduced almost to routine, so fortunate have the engineers been with their cathode-ray oscillographs or millionth-of-a-second cameras.

At Wallenpaupack, Pa., where the first record was obtained last year, the engineers had obtained more than a score of the pictures before the middle of July this season, and other engineers with similar equipment had secured like records along high voltage transmission lines in Ohio. And those obtained this year support the revelations of last year's observations,—that when lightning strikes a transmission line, or causes a voltage surge by induction, the voltage in the line frequently is built up to an extremely high value—often millions of volts—in a few millionths of a second, drops to half the value within another few millionths of a second, and returns to normal voltage within less than one hundred micro-, or millionths, seconds.

At Wallenpaupack, where engineers of the General Electric Company are co-operating with engineers of the Pennsylvania Power & Light Company in investigations on its 220,000 volt transmission system for the fourth consecutive year, the equipment has been augmented this season by the addition of a second cathode-ray oscillograph as well as more surge voltage recorders, lightning measuring antennae and other special equipment at intervals along the 65 mile line extending from Wallenpaupack to Siegfried.

At Newcomerstown, Ohio, where a similar lightning record has been obtained this season, the General Electric Company engineers are co-operating with the American Gas and Electric and the Ohio Power Companies, employing one oscillograph and a number of surge voltage recorders along the Philo-Canton 132,000-volt transmission line.

The records do not represent just one storm but a series of storms, the first of the season having been on May 3rd.

In the case of the picture obtained in 1928, it was determined that the lightning caused the voltage to rise to an extremely high value in eight millionths of a second, to drop to half that value in another nine micro-seconds, and to be back to normal in a total of 35 microseconds. Last year's record also showed that the lightning caused an arc-over of the insulators of one or the other wires of the three-wire system, this arc-over being indicated in the record by a rapid oscillating of the beam of cathode rays. This lightning surge reached a peak of about 2,500,000 volts at a distance of 17 miles from the oscillograph, as measured by a surge recorder.